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LANDSAT D

DATA PROCESSING FACILITY STUDY

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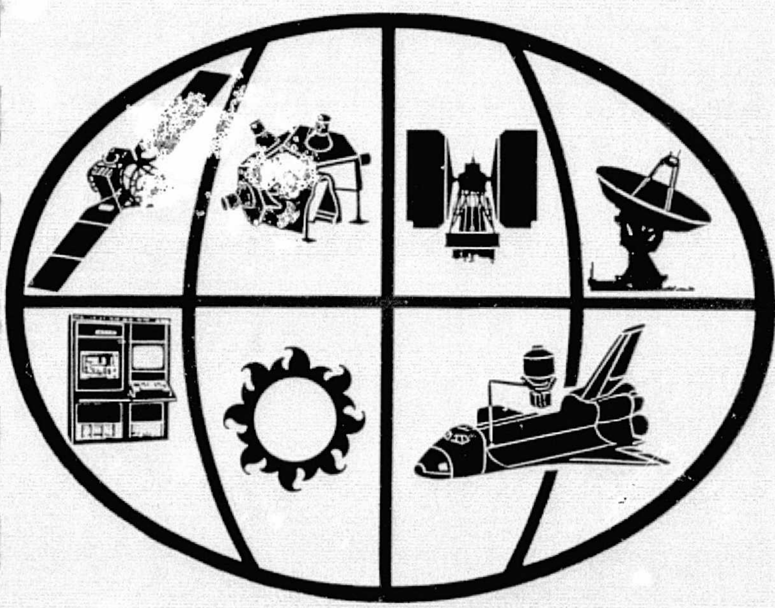
FINAL REPORT

Prepared for
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771



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INTRODUCTION AND SUMMARY

1.1 BACKGROUND

The pressing need to better survey and manage the earth's resources and environment has prompted man to explore the possibilities of remote sensing from space. Early efforts began with space photographs from the Gemini and Apollo programs and continued with multispectral data from Landsat 1 and 2 spacecraft. Landsat D is currently planned as the next major step for the Earth Resources Program.

Landsat 1, launched in 1972, marked the start of NASA's Earth Resources satellite program. This successful spacecraft was followed two and a half years later with Landsat 2, an identical spacecraft. The overwhelming success of these two Landsats, demonstrated through hundreds of experimental programs, has motivated NASA to continue to improve the Earth Resources satellite program. The third satellite, Landsat C, has been procured and is scheduled for launch in late 1977. This third satellite will carry a modified multispectral scanner and will utilize an improved digital ground system. NASA is now planning for the next step, Landsat D, which will provide several major advances. Landsat D will incorporate the Thematic Mapper (TM) as a new sensor, it will utilize the Multi-Mission Modular Spacecraft (MMS), it will make use of the Tracking and Data Relay Satellite System (TDRSS) and it will employ a new more advanced ground system. Each of these represent significant improvements in the state-of-the-art. This study is one of several which address various aspects of the planned Landsat D system.

As the Earth Resources Program has matured through the Landsat spacecraft it has begun the transition from an experimental research activity to a sound demonstration of proven utility. This important transition will be completed with the Landsat D system which incorporates several key improvements over the current system. These improvements, based on experience with the existing Landsats, will provide new capabilities in the spacecraft, the sensor, the ground system, and the overall system design. These system

capabilities - which emphasize improved vegetation analysis, prompt availability of data, frequent coverage, and precise data registration and overlay for better change detection will permit the Landsat D to capture already proven economic benefits in such diverse applications as:

- Monitoring world-wide food productivity
- Mapping agricultural land use
- Monitoring rangelands
- Surveying forest resources
- Managing critical watersheds
- Detecting land use changes
- Oil/mineral exploration

An artist's concept of the Landsat D system is shown in Figure 1-1. The spacecraft will be based on NASA's new Multi-mission Modular Spacecraft (MMS) and will operate two remote sensing instruments: a Thematic Mapper (TM), with 30 meter ground resolution, and a Multispectral Scanner (MSS), with 80 meter resolution. The system provides two data communication paths to the Earth; one is a direct readout link for ground stations (both

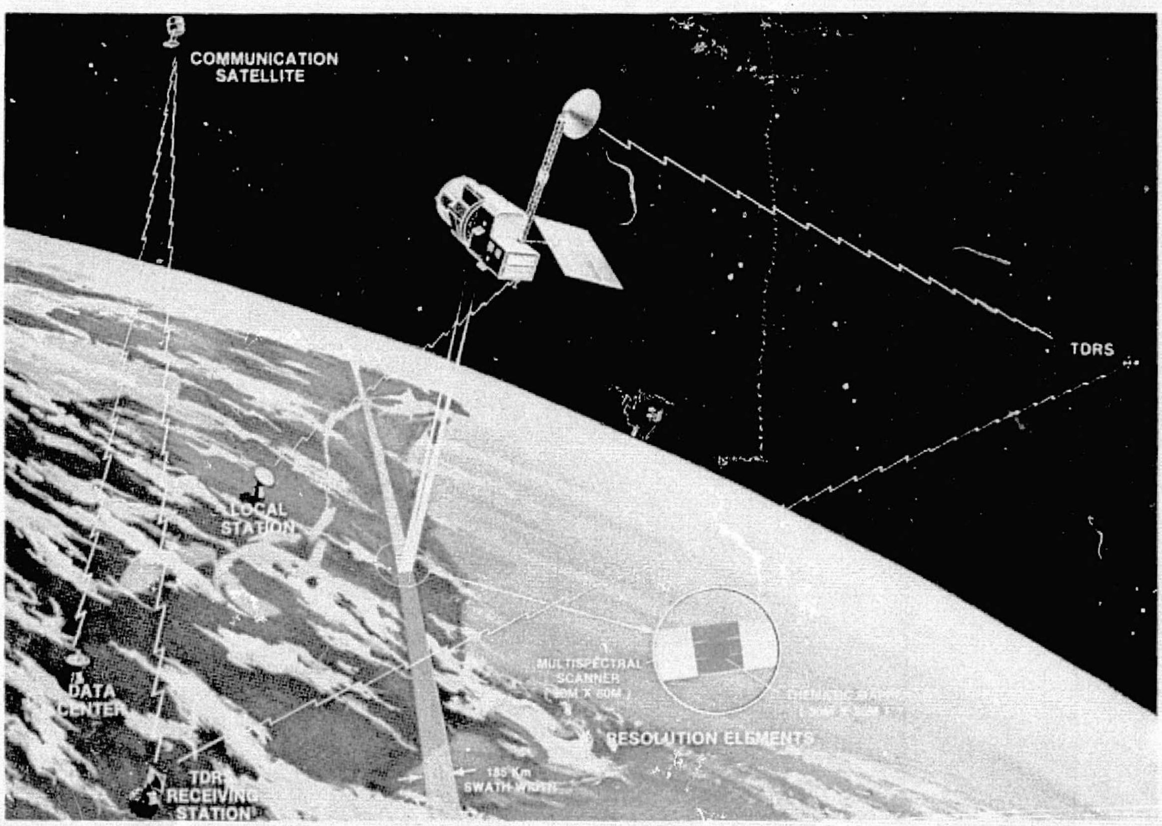


Figure 1-1. Landsat D System

domestic and foreign) within range of the spacecraft, and the other is a relay link via the Tracking and Data Relay Satellite System (TDRSS) for nearly full global coverage. The spacecraft will be in a sun-synchronous orbit with a descending node time of 9:30 AM (similar to current Landsats). The orbital altitude and inclination will provide near global coverage of the land and near coastal regions with a repeat cycle every 16 to 18 days.

The use of the new MMS spacecraft as the basic bus will provide both improved sensor pointing accuracy (±0.01 degree) and stability (10^{-6} degrees/second). These improvements will manifest themselves in more accurate and more straightforward geometric corrections of the image data; both relative (image to image) and absolute (with respect to the Earth's surface). The MMS incorporates modular subsystems in the key areas of power, attitude control, and command and data handling. This modularity together with the compatibility for both conventional and Space Shuttle launches will enable in-orbit repair and refurbishment of the spacecraft.

The Thematic Mapper, TM, is an evolutionary improvement of the MSS and provides several significant capabilities. The spatial resolution on the ground has been reduced to 30 meters (compared to 80 for the MSS) which will allow radiances to be measured for areas (pixels) less than one sixth the size as for the MSS. The TM will incorporate six spectral bands (and have the capability for a seventh) which have been located primarily on the basis of their ability to discriminate vegetation (a fundamental application of remote sensing). In addition the radiometric sensitivity of the TM has been improved by reducing the signal-to-noise characteristic and increasing the levels of digital quantization. These sensor changes combine to cause the TM to have a data rate of 120 Mbps, (an order of magnitude increase over the 15 Mbps of the MSS).

For remotely sensed multispectral data to be truly practical for many potential operational users (agricultural analysts, hydrologists, etc.) it must be received by them in usuable form within 48 to 96 hours after imaging. Promptness in receiving data products is one of the most critical aspects of the Landsat System.

The Landsat D System will be thoroughly integrated with the needs of operational users. It will include improved preprocessing of all data, central data processing, archiving and retrieval,

low-cost receiving and data centers for large volume users (such as the U. S. Department of Agriculture) and provide maximum efficiency and economy in utilization by state, regional, and foreign users. Featuring the rapid electronic transmission of all data, the Landsat Follow-on system will reduce the time between satellite imaging and user reception of data to the required 48 to 96 hours.

As illustrated in the artist's concept the system provides two data links to the ground. The first link, for both MSS and Thematic Mapper data, is directly from the satellite to domestic and foreign ground stations as the satellite passes through their reception areas. The second link is via the Tracking and Data Relay Satellite System (TDRSS). As shown, the data is transmitted to a TDRSS satellite, in stationary orbit, and relayed to the TDRSS receiving station. The TDRSS receiving station transmits the data via a domestic communications satellite to a central data processing facility that, in turn, relays the data to any local data distribution center equipped to receive it.

This link, via TDRSS and the communications satellite, will thus have global acquisition and relay capabilities, providing rapid access to Thematic Mapper data for users throughout the world. Both data links have a planned maximum data capability of 135 Mb/second at a 10^{-5} bit error rate.

The Landsat D system described is currently in the planning stages by NASA. As part of the planning for this future system, NASA has undertaken a series of studies, with General Electric and others, to investigate various system options. This particular study is one of seven conducted by General Electric to explore different aspects of the total ground system that will be required by Landsat D in order to meet the overall mission objectives.

The seven ground system studies are:

1. Local User Terminal Study - an investigation into the requirements and options available for direct readout (primarily foreign ground stations) of Landsat D data.

2. User Data Processing Study - an effort to estimate the scope, size, and cost of the major user data processing system requirements.

3. Data Processing Facility Study - a requirement and sizing study to provide preliminary estimates of the scope and cost of NASA's central Landsat D data processing center.

4. GSFC Research & Development Study - a survey and analysis of the functions and facility required of NASA to continue the basic research on spaceborne remote sensing and its applications.

5. Operation Control Study - an analysis of the modifications necessary to up grade or modify the NASA Operations Control Center (OCC) for Landsat D.

6. Data Transmission and Dissemination Study - an investigation into the options and limitations of various data communication alternatives including centralization versus decentralization.

7. Position Determination and Correction Study - an analysis of the impact and alternatives afforded by the MMS spacecraft of Landsat D on image geometric correction.

1.2 THE LANDSAT D GROUND SYSTEM

A top-level functional diagram of the Landsat D ground system is presented in Figure 1-2. The five major subsystems included are the Data Input Subsystem (DIS), the Central Data Processing Facility (CDPF), the Product Generation and Dissemination Facility (PGDF), the Data Management Subsystem (DMS), and the Agriculture Utilization Subsystem (AUS). Each of these subsystems is briefly described below.

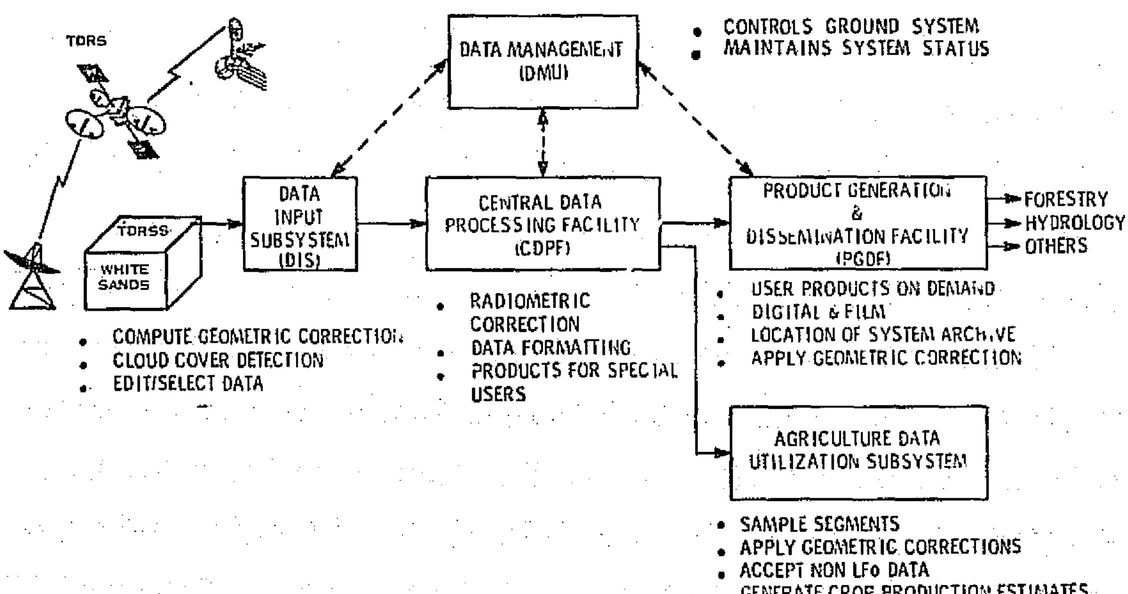


Figure 1-2. Ground System Concept

The Data Input Subsystem (DIS) receives 120-135 Mbps data from the TDRSS via dedicated cable interconnection. The prime functions of the DIS are to record the raw input data, to perform cloud cover detection and scene editing, and to compute geometric correction matrices on a per swath basis.

The Central Data Processing Facility (CDPF) receives edited data from the DIS and performs standard operations to all data. These operations include radiometric correction and data reformatting to a band-interleaved-by-line (BIL) format.

The Product Generation and Dissemination Facility (PGDF) is the main interface between the Landsat D ground system and general users. This facility provides Landsat D data, in either digital tape or film format, to users on demand. The data, which may be geometrically corrected to various map projection systems or enhanced as requested by the user, is available in a variety of sizes, formats, and media. The PGDF also houses and manages the system archive.

The Data Management Subsystem (DMS) provides the central point of control and data base management for the Landsat D ground system. Its prime functions include management of user demand, the system archive, system communications, and system redundancy. The DMS also maintains system status, production statistics, operations logs and administrative services.

The Agriculture Utilization Subsystem (AUS) receives data directly from the CDPF and performs those operations necessary to produce world crop production forecasts on a periodic basis. The operations to be performed include geometric correction, sample segment extraction, multispectral analysis, and areal and statistical analyses. It is included here as part of the ground system because it represents the first major user of Landsat D data.

Several other major subsystems included as part of the Landsat D ground system were considered. These include the Operations Control Center (OCC), the GSFC Research and Development Facility, and the Hydrologic Land-Use Utilization Subsystem. The OCC performs the functions required to plan, schedule, operate and evalute spacecraft and payload

operations. The R&D Facility enables NASA to perform research related to the Landsat program and its applications. The Hydrologic/Land Use Utilization Subsystem is similar in concept to the AUS and will generate land use maps over watershed areas within the U. S.

1.3 DATA PROCESSING FACILITY SUMMARY

This study will provide a detailed analysis of viable options for the implementation of a Data Processing Facility to satisfy the Landsat D mission requirements, considering location, product types and product quality as well as predicted throughput and timeliness criteria. A conceptual design for the selected ground system will be developed, and system costs (both recurring and non-recurring) will be derived and presented.

Section 2 will examine the design requirements of the Data Processing Facility. These requirements, in the areas of data acquisition, data processing, information storage and retrieval, product generation and distribution, process management, and user interface, are factored into each design option.

Section 3 looks at the critical areas of the design and describes the analysis and system tradeoffs that were performed. Key trades such as distributed vs. centralized processing, hardware vs. software processing, and overall data management are some of the significant analyses discussed.

The final design for each subsystem comprising the Data Processing Facility, DPF, is presented in Section 4 together with the supporting system design block diagrams to the major equipment/box level. This design is for the "full up" system option capable of satsifying the entire repertoire of Landsat D mission requirements. The "full up" option was the major focus for this study contract.

In addition to the basic "full up" system design, several alternative design options were investigated to various degrees. This investigation into design alternatives, corresponding to revisions in the system requirements, is presented in Section 5. These alternative designs in general represent smaller systems of lower capability. It is recognized that the user demand for the products will change as the system operates and

matures, and that significant impact will be felt as specific user programs undergo the transition from a research and development status to an operational status. The Landsat D Data Processing Facility was designed to take such changes into account; thus flexibility and adaptability provisions are incorporated into the alternative designs as a fundamental design requirement.

As part of this study effort, cost estimates were developed for the Data Processing Facility and its major subsystems. These estimates are presented in Section 6 together with the cost estimating procedures used to develop them.

SECTION 2

IMAGE DATA PROCESSING REQUIREMENTS

2.1 DATA ACQUISITION

The Data Processing Facility data acquisition design requirements are concerned with receiving the satellite data and necessary ancillary inputs and providing recorded output. In brief, the data acquisition equipment must:

- Accept 120 - 135 Mbps data from satellite sensors via TDRSS.
- Accept predicted spacecraft ephemeris data from ground computers.
- Accept TDRSS generated ground time signals.
- Interface with TDRSS controls.
- Record data/predicted ephemeris/time on High Density Digital Tapes (HDDT).
- Provide capability for no data dropouts greater than 10 seconds for any single equipment failure.
- Provide a mechanism to automatically switch from one data recorder to another with no loss of data.
- Provide operational status to the Redundancy, Communication, and Data Management Subsystems.

2.2 DATA PROCESSING

The Data Processing Facility design requirements for data processing are concerned with accepting the recorded satellite data/predicted ephemeris/ground time data and providing output data tapes consistent with user required corrections and format. In brief, the data processing equipment must:

- Accept data input from the Data Acquisition equipment.
- Separate TM and MSS data prior to recording.
- Generate cloud cover statistics and store them for future data editing.

- Process input data and rearrange to formats compatible with user requirements.
- Provide radiometric correction for all sensor inputs.
- Provide geometric correction for input data.
- Provide control point location.
- Provide scene reformatting.
- Generate output data recordings in HDDT and CCT tapes, film recordings, and visual displays.
- Provide control mechanisms and sufficient spares such that failures can be corrected and lost processing time made up within one work shift.

2.3 INFORMATION STORAGE AND RETRIEVAL

The information storage and retrieval system design requirements are concerned with the inventory, labelling, and locating of data tape recordings. The basic requirements are:

- Assign ID number and storage location for new Data Input Subsystem (DIS) tapes, classified by time of data, scene ID numbers, and scene location.
- Generate DIS tape labels.
- Accept data queries from terminal units and respond with physical location of tape, i.e., archive rack number, reformatter, etc.
- Provide means to electronically identify data tapes from their labels.
- Change tape location automatically in memory whenever tape is identified as being in a new location in the Landsat D ground system.
- Assign ID number and storage location for new Central Data Processing Facility (CDPF) data tapes made by processing original DIS data. Classify tapes by data time, scene ID numbers and scene locations.
- Generate statistics regarding data on file (areas covered, number of data tapes, cloud cover, whether processed data is available, etc.)

2.4 PRODUCT GENERATION AND DISSEMINATION

The primary product generation and dissemination requirements include the following:

- Geometrically correct up to 250 TM scenes per day, based on user demands.
- Provide the user a selection of standard map projections including Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, etc.
- Correct geometric distortions to $\pm$ .5 pixel accuracy.
- Provide the capability to duplicate or copy various format digital tapes based on user demand.
- Provide the capability to generate 16 mm microfilm of one MSS band for browse purposes.
- Provide the capability to generate and photo process 250 scenes per day on precision 9-1/2" film.
- Provide the capability to reformat archival tapes from band interleaved-by-line format to band sequential format prior to generation of film products.
- Provide the capability for special image processing and enhancement such as:
  - Gamma Compensation
  - Level Slicing
  - Dynamic Range Adjustment
  - Edge Detection
  - MTF Compensation
  - Digital Filtering

2.5 PROCESS MANAGEMENT

The primary process management requirements include the following:

- Provide centralized control, data management, user transaction processing and digital image pipeline process control.
- Maintenance of long term archive.

- Rapid response to user requests for a variety of digital image products.
- Achievement of a high degree of automation, thus eliminating a labor intensive operational environment.
- Accept predicted ephemeris from the Orbit Determination Group.
- Detect equipment failures and provide for automatic switchover and redundancy in critical areas.

2.6 USER PRODUCT DEMAND

The primary user product demand requirements include the following:

- Provide the capability to process a variety users' requests for digital products and services.
- Service and response to user demands should be timely.
- Provide access to system by high volume users, as well as low volume users.
- Provide the capability to service special user requests for custom enhanced products, as well as standard products.
- Convert user demands automatically into production scheduling.

SECTION 3

SYSTEM ANALYSIS

3.1 DISTRIBUTED PROCESS CONTROL

The Data Processing Facility involves extensive use of hierarchical control and distributed processing techniques common to the design of many large ground systems currently in use or in development. For example, the Launch Processor System (LPS) currently being developed by Kennedy Space Center utilizes the concept of a distributed network of minicomputers in a variety of functional roles to perform prelaunch checkout of the Shuttle vehicle. GE has employed the distributed network concept in the design of several large satellite ground systems, including the TDRSS Ground System. A key step in the design of the ground system was functional partitioning based on system processing functions and pixel rates.

The Data Processing Facility design incorporates a hierarchical control concept which utilizes a centralized Data Management Subsystem (DMS) as the primary focus of control with sublevels of control functionally distributed to local controllers (e.g. Tape Scheduler Unit, Browse Generator Control Interface Unit, Radiometric Corrector Control Interface Unit, etc.). The partitioning of control functions is based primarily on real-time control response time requirements and loading considerations. The Data Processing Facility can be viewed as consisting of four major segments, excluding the Operations Control Center function.

The major partitions include the Data Input Subsystem (DIS), Central Data Processing Facility (CDPF), Product Generation and Dissemination Facility (PGDF), and the Data Management Subsystem (DMS). The function of the DMS is to maintain control of the process flow in the rest of the system. The primary control transactions between the DMS and the rest of the system occur at a once per scene rate. Processing in the DIS, CDPF, and PGDF occurs at the nominal pixel rate for each segment, depending on loading. Local control functions within the DIS, CDPF, and PGDF occur at the scan-line rate or greater. The DIS and CDPF receive overall mode control, tape scheduling, cloud cover editing, radiometric correction and redundancy management control commands from the Data Management Subsystem. The PGDF receives overall mode control,

tape scheduling, geometric correction, tape reformatting, film generation and tape duplication control commands from the Data Management Subsystem.

3.2 PIPELINE PROCESSING

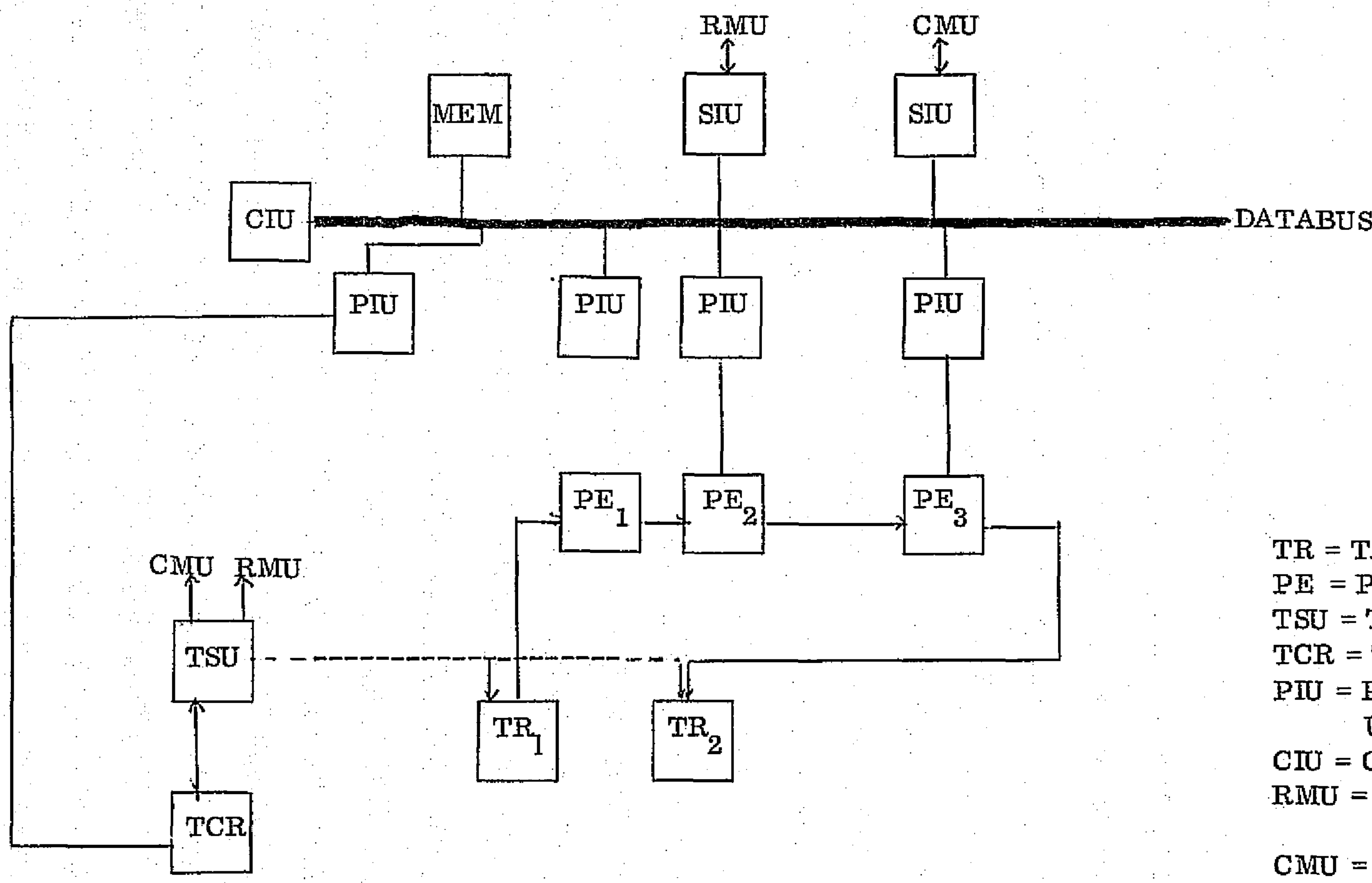
When processing large amounts of data, or when data rates become fairly high, the technique of pipeline processing is not only feasible, but ofttimes mandatory. The term "pipeline" is derived from the similarity of the processing system to a straight length of pipe; data is poured into one end of the pipe, it traverses, and exits from the other end modified only by elements within the pipeline itself.

Figure 3-1 illustrates a typical pipeline process which could be any of the sub-level pipeline processors to be used in the ground system. The actual pipeline consists of the data input element tape recorder (TR_1), three serial pipeline elements (PE_1, PE_2, PE_3), and the data output element tape recorder (TR_2). In this case input data is read from a tape, modified in PE_1, further processed in PE_2, and modified again in PE_3; then recorded as output data onto another tape.

Control of the pipeline and other ancillary equipment is accomplished through a databus. The Tape Scheduler Unit contains or has access to a table which lists the commanded sequence of events. TR_1 will be commanded to start by the Tape Scheduler Unit. Output from the time code channel on the tape is input to the Time Code Reader, which tells the Tape Scheduler Unit where the tape currently is operating. The Time Code Reader also instructs the Control Interface Unit of the current tape time. When current tape time equals desired pipeline start time, a comparator in the first Parallel Interface Unit generates an interrupt to the Control Interface Unit, which tells the pipeline elements to begin processing. It further instructs TR_2 to begin recording output data.

The various pipeline elements PE_1, PE_2, and PE_3 interact with the databus through their own Parallel Interface Units. Access to memory, the Redundancy Management Unit and the Communication Management Unit is under Control Interface Unit control through the databus.

As the process continues, the Tape Scheduler Unit is stepped from command to command in its look-up table. These commands are input to the databus and cause the Control



TR = TAPE RECORDER
PE = PIPELINE ELEMENT
TSU = TAPE SCHEDULE UNIT
TCR = TIME CODE READER
PIU = PARALLEL INTERFACE UNIT
CIU = CONTROL I/F UNIT
RMU = REDUNDANCY MGMT UNIT
CMU = COMMUNICATIONS MGMT UNIT
SIU = SERIAL INTERFACE UNIT

Figure 3-1. Pipeline Processing

Interface Unit to generate appropriate, timely instructions to the other elements in the subsystem.

The proposed Data Processing Facility is essentially a group of pipelines operating under master control provided by the Data Management Subsystem.

3.3 DEMAND TRANSACTION PROCESSING

The Data Processing Facility provides the capability to service a variety of user requests for image products. The Product Generation and Dissemination Facility (PGDF) portion of the Data Processing Facility is demand oriented, in that user requests to the Data Processing Facility are scheduled by the Data Management System (DMS) and process sequences are initiated in the PGDF to generate the requested product. Demand transactions are initiated by entry of a user service request via the Demand User Subsystem terminals. The Demand User Subsystem issues a product request to the Data Management Subsystem for subsequent scheduling and processing. The Data Management Subsystem enters the product request in the appropriate process queue and determines the status and location of the archive tape containing the desired image. If the desired image is available in the archive, the Data Management Subsystem (DMS) will issue a tape retrieval request to the appropriate Archive Station Communication Unit (ASCU) operator. Furthermore, scheduling information concerning the processing of the specified tape will be generated and maintained by the Data Management Subsystem (DMS). Once the specified tape is mounted on the PGDF unit's input device, and the tape is identified via the ASCU, the DMS will route the processing schedule to the proper PGDF units, initiate processing and maintain the process status. Upon completion of the processing of the image product, the DMS is notified, thus completing the transaction. Additional functions performed by the DMS include daily production statistics, product accounting, user billing and shipping invoices.

3.4 DATA BASE MANAGEMENT

The design concept utilized for centralized control and data management in the Data Processing Facility distributed network involves the use of a Data Base Management System (DBMS). The DBMS allows the system operator to define both the logical and physical characteristics of the data base in a flexible manner, utilizing the Data

Definition Language capability of the system. Once the data base schema and subschemas are defined and generated, the application programs and Real Time Executives in the network exercise the data base by logically referencing the desired data. The mechanism by which the logical to physical translation is performed is transparent to the application programmer as shown in Figure 3-2. Once the database has been implemented, the application programmers can use the DBMS to store, process, and maintain the data within the data base. The mechanism by which the application programmer utilizes the database is called the Data Manipulation Language or any host language which supports a CALL statement or equivalent. Thus the application programmer communicates with the database by passing arguments through CALL statements or Data Manipulation Language in the application program itself.

3.5 DATA REDUCTION TECHNIQUES

The Data Processing Facility design incorporates a sophisticated data reduction technique in the Data Input Subsystem. The nominal input sensor data volume from TDRSS is 1768 Thematic Mapper scenes per day*. This volume of data includes both valuable and unwanted scenes. The objective of the data reduction techniques utilized is to eliminate cloud covered scenes based on an accurate multispectral signature method. Once having determined a scene to be cloud covered or otherwise unusable, the scene is automatically edited from the raw image data prior to further processing. Significant reductions in the amount of processing are realized (e.g. approximately 1330 scenes per day are estimated to be rejected due to the various criteria). This reduces the size of the tape archive and minimizes operating costs. Accurate records of available scenes are generated and maintained by the Data Base Management System for demand users.

3.6 FAULT DETECTION AND REDUNDANCY

The Data Processing Facility design incorporates a system monitoring function for the detection of equipment failures or anomalies which occur during the real-time operations. The most critical portion of the system in terms of acquisition of data is the Data Input Subsystem (DIS). The DIS is the only portion of the system which has redundant units and automatic switch over to assure continuous recording of raw sensor data. The remaining

*2 spacecraft

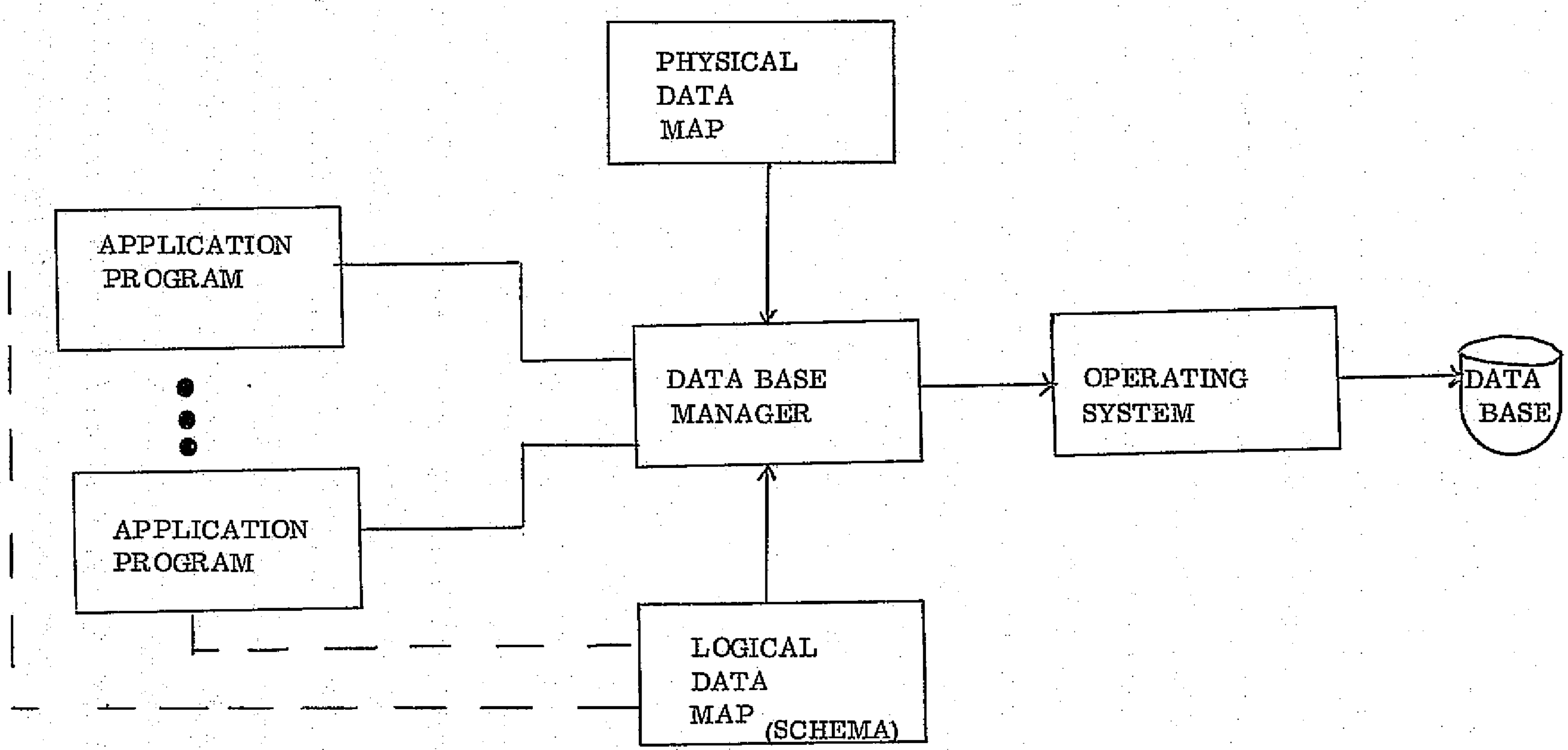


Figure 3-2. DPF Data Base Manager

portions of the design are fully redundant, thus the Redundancy Management System only detects equipment failures and reports the anomaly to the system operators. Sparing and maintenance philosophies will govern the ultimate availability of this portion of the system.

3.7 ARCHIVE MANAGEMENT

All information storage in the Landsat D ground system is done on magnetic tape and is under the control of the Data Management System (DMS). Storage (physical) is in either a long term archive or a rapid access archive.

As new data tapes are generated, they are identified by the DMS and a label for each tape is generated at the station where the recording is taking place. The label contains a description of the data, its programmed location in the archive, and a bar code enabling it to be read by a wand-type reader at any location in the ground system.

When a tape is not at its assigned location in the archive, the DMS maintains in memory the current location. This is accomplished through an input to the DMS when an operator reaches a new location with a data tape. He reads the tape label with the station wand, thus providing tape ID and location to the DMS memory. As long as the tape remains at that location the DMS memory retains the information. When moved to a new location, or back to the archive, the change in status is noted by the DMS. In this fashion the location of any tape in the data base is assured.

Data as received by the Data Input Subsystem (DIS) is identified to the DMS by the operator at the DIS. The current time, satellite location, and the data tape number are identified at the DIS, verified by the operator using his terminal unit, and the new tape label is generated for the data reel.

It is anticipated that each archive (tape and film) would require several people to service requests for data as they are received. The DMS would display requests to these operators on terminal units within the archive, and they respond by locating the recordings. The reels of tape would then be transported by hand, cart, or scooter, to the requesting location for processing. Upon completion of processing, the using location notifies the DMS of the completion of tape usage, and the tape is picked up by archive personnel for return to storage. It is expected that the location of all tapes by the DMS would be instantaneous.

SECTION 4

DATA PROCESSING FACILITY DESIGN

4.1 DATA MANAGEMENT SUBSYSTEM (DMS)

4.1.1 DATA MANAGEMENT UNIT

The Data Management Unit provides the central point of control and data base management in the Data Processing Facility design. The Data Management Unit is interfaced to the Demand User Subsystem, Archive Management Subsystem, Communication Management Subsystem, Redundancy Management Subsystem and the Operations Control Center as shown in Figure 4-1. The DMS accepts user product demand requests from the Demand User Subsystem, issues archive retrieval requests to the Archive Management Subsystem and generates processing schedules for the Product Generation and Dissemination Facility (PGDF). The DMS maintains the Data Processing Facility configuration table in its database and is updated by the Redundancy Management Unit in the event of any system anomaly. The Communication Management Subsystem offloads the DMS from the front-end communications handling functions associated with the DIS, CDPF, and PGDF. The Archive Management Subsystem which consists of the multiple Archive Station Communication Units (ASCU's) allows the DMS to monitor the generation of all digital tape products and to identify and track the processing of the HDDTs, HDTs and CCTs throughout the system.

The DMS accepts predicted ephemeris data from the OCC and routes the data to the Swath Correlator Unit via the Communications Management Unit. The DMS receives Geometric Correction information and cloud cover statistics from the DIS on a periodic basis and generates the header information and editing schedules utilized in the CDPF. Radiometric correction coefficient tables are routed to the Radiometric Correction Control Interface Unit on a per scene basis via the Communications Management Unit.

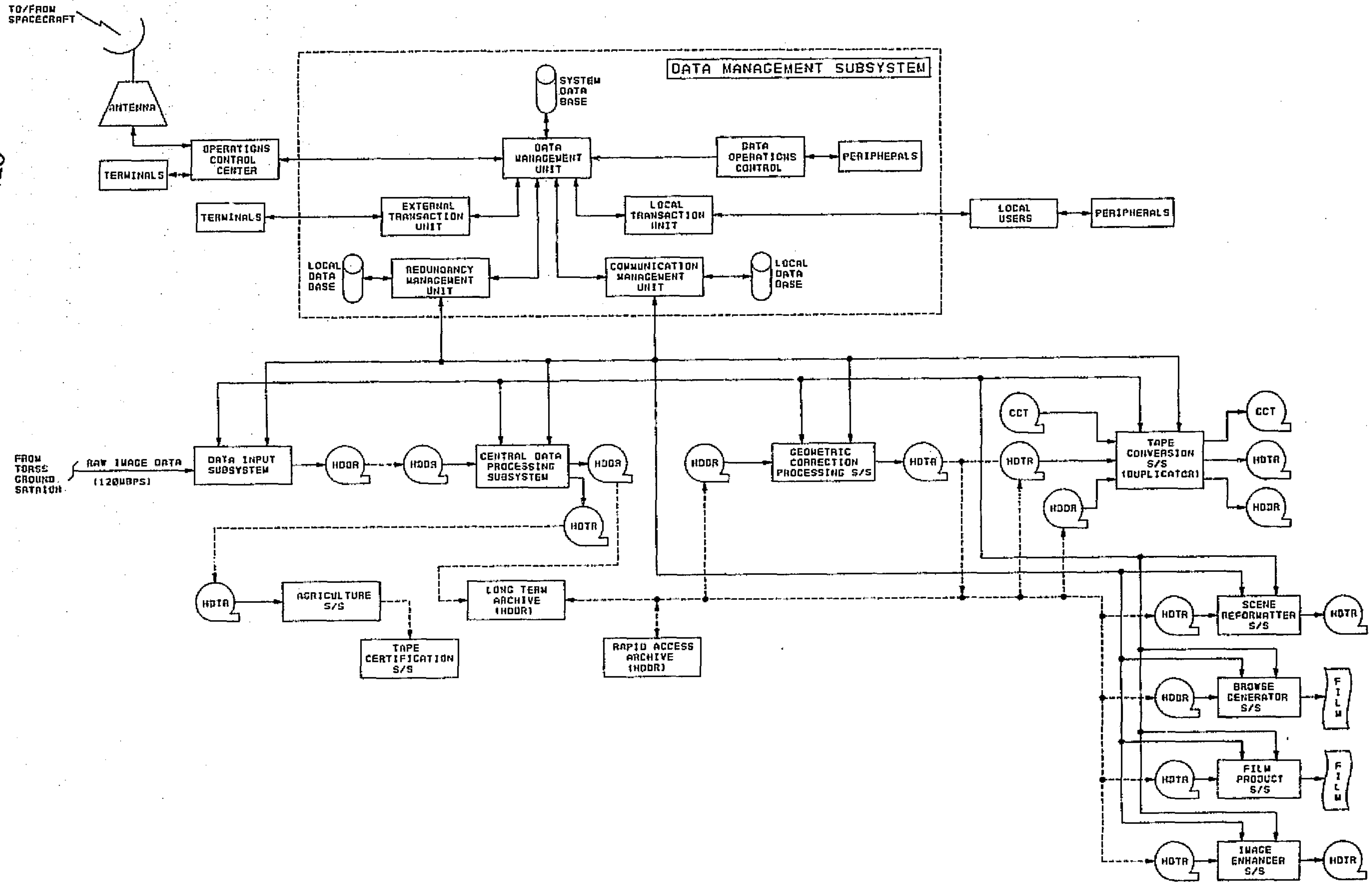


Figure 4-1. Landsat D Ground System Data Management Subsystem and Overall System Diagram

The Data Management Unit also served as a general housekeeping, management and accounting facility within the Landsat D ground system. It maintains system status and an up-to-date inventory of system spares. Production statistics and operations logs are computed and maintained for the entire ground system and are available on a continuous basis to system operators. Finally, the Data Management Unit is used to assist in administrative services such as accounting, payroll, benefits, management reports, trend analysis, etc.

4.1.2 DEMAND USER SUBSYSTEM

The Demand User Subsystem provides the primary interface from the DMS to the outside world. The Demand User Subsystem consists of the Local Transaction Unit and the External Transaction Unit and their associated peripherals and data links. The Local Transaction Unit and the External Transaction Unit both function as front-end processors or transaction concentrators which accept remote or local terminal inputs, then format and issue product or service requests to the DMS. The Local Transaction Unit supports a number of output devices utilized by the administrative services office to monitor the operation of the ground system.

4.1.3 ARCHIVE MANAGEMENT SUBSYSTEM

The Archive Management Subsystem provides the capability to monitor the generation of archive tapes, automatically identify and track each individual tape, request tape retrieval from the archive, and issue instructions to tape unit operators. The Archive Management Subsystem consists of a network of interrelated processors and functions within the ground system. The key elements include the Data Management Unit, Communication Management Unit, Archive Station Communication Units (ASCU) Tape Scheduler Unit, Tape Certification Subsystem and the tape archive. The DMS monitors the generation of tapes via the Tape Scheduler Unit and the Archive Station Communication Unit. Once the output tape is initiated in the DIS, the Tape Scheduler Unit notifies the DMS, who in turn opens a new tape entry in the data base containing pertinent information relating to the tape being generated (e.g., start time, stop time, satellite number, swath number, tape identifier, etc.). Once the new tape is generated and unmounted, the DMS issues a message block to the proper Archive Station Communication Unit (ASCU) requesting the generation of a tape label for the new tape. Once the label is affixed to the tape, the ASCU operator

passes the wand over the unique bar code identifiers on the label and the ASCU formats and routes the unique identifier to the DMS via the Communication Management Unit. A similar process occurs in each subsystem, where the ASCU is used in conjunction with the Tape Scheduler Unit to uniquely identify each input tape prior to initilization, scheduling and processing operations. Retrieval of tapes from the archives, identification and monitoring of the status of any tape in the system is simplified by the use of the ASCU wand and the operator interface, when used in conjunction with the DMS.

4.1.4 COMMUNICATION MANAGEMENT SUBSYSTEM

The Communication Management Subsystem is the front-end transaction processor in the ground system. It interfaces directly with the Data Management Unit, Redundancy Management Unit and all processing units in the DIS, CDPF, and PGDF including the Geometric Correction Subsystem, the Tape Duplication Subsystem, the Tape Reformatter Subsystem, the Browse Generator Subsystem, the Film Generation Subsystem and the Image Enhancement Subsystem. The Communication Management Unit provides command and data distribution functions in response to transfer requests from the DMS. All incoming interunit messages to the DMS are buffered, formatted and routed to the DMS for processing. Additional functions include down-line loading for the ground system, system safing in the event of Data Management Unit failure and alternate interunit routing of failure messages to the Redundancy Management Unit in the event of Redundancy Management Unit link failures.

4.1.5 REDUNDANCY MANAGEMENT UNIT

From a reliability standpoint, the most critical area in the Landsat D ground system is the Data Input Subsystem (LIS) since the data stream from the TDRSS is continuous and uninterrupted. A failure of equipment here would result in data loss which cannot be made up. The other subsystems are not as critical since processing of the master data tapes is done selectively and no data would be lost. Equipment down time, when greater than 30 minutes, may necessitate the addition of a third shift to make up time, but the time and data processing can indeed be made up.

Examining the DIS, it is seen that data flow from subsystem input to tape is straightforward from input, through patch panel, to the appropriate HDDR,* and onto tape.

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*There are two types of high data recorders, HDDR is used to refer to the 120 Mbps (42 track) recorder and HDTR is used to refer to the 20 Mbps (14 track) recorder.

Considering recorder malfunction or tape breakage as failure modes, the obvious solution is to provide a backup HDDR. Normally data does not flow directly to HDDR, but is first processed to generate cloud cover statistics and locate control points. The equipment to accomplish this is not redundant, as the processing is not mandatory in real time whereas the data recording requirement is absolute.

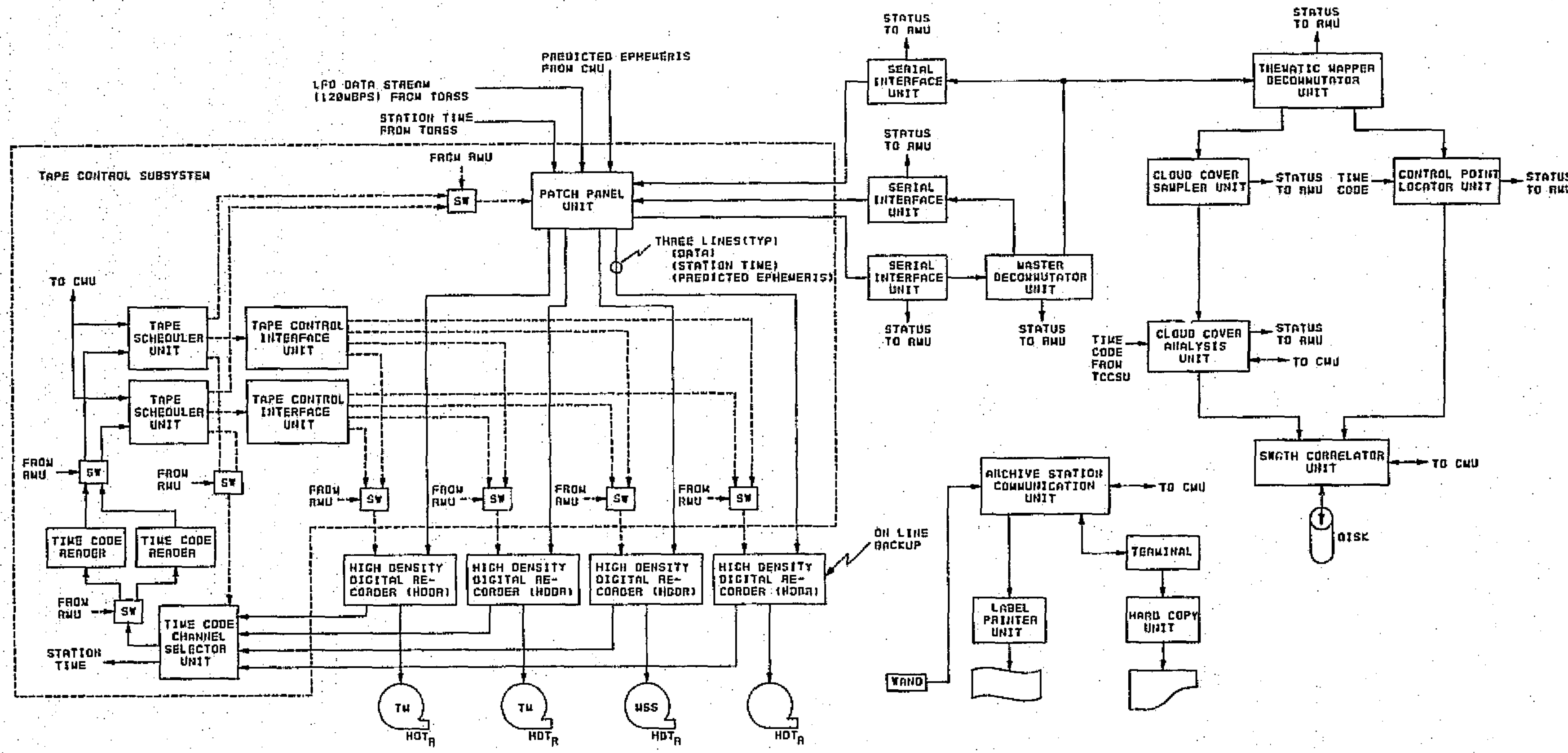
Each recorder is controlled by the Tape Control Interface Unit which is programmed by the Tape Scheduler Unit. Commands from the Communication Management Subsystem and actual data time from the Time Code Reader provide input stimulus to the Tape Scheduler Unit. Status reports from the recorders, processing elements in the data stream, and control elements are received by the Communication Management Unit and the the Redundancy Management Unit, processed by the Redundancy Management Unit, and result in control commands to change data routing and/or select redundant equipment as system demands occur. The Redundancy Management Unit also provides status to the Communication Management Unit for output and display to the system operation personnel.

Status from the other subsystems is supplied to the Redundancy Management Unit through the Communications Management Unit and the databus. Although no actual switching of data results, the Redundancy Management Unit can direct the Communications Management Unit to halt a processing operation due to failures or equipment malfunctions which are detected.

4.2 THE DATA INPUT SUBSYSTEM (DIS)

The Data Input Subsystem receives and records data from TDRSS, generates cloud cover statistics and locates control points, and provides information to the Communications Management Unit regarding status of input data. Figure 4-2, The Data Input Subsystem, is a block diagram of this subsystem and should be used to follow the signal paths in the following discussion of subsystem operation.

Data input to the DIS consists of a 120-135 Mbps data stream, station time from the TDRSS and predicted ephemeris from the Communication Management Unit. These inputs go to the Patch Panel Unit where they are routed under computer control to a



EQUIPMENT LIST	QTY	
TAPE CONTROL I/F UNIT	2	
TAPE SCHEDULER UNIT	2	
TIME CODE READER	2	
TIME CODE CHANNEL SELECTOR UNIT	1	
HIGH DENSITY DIGITAL RECORDER	4	
PATCH PANEL UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	
SERIAL INTERFACE UNIT	3	
MASTER DECOMMUTATOR UNIT	1	
TM DECOMMUTATOR UNIT	1	
CLOUD COVER SAMPLER UNIT	1	
CLOUD COVER ANALYSIS UNIT	1	
SWATH CORRELATOR UNIT	1	
CONTROL POINT LOCATOR UNIT	1	
CONTROL PATH SWITCHES	7	

Figure 4-2. The Data Input Subsystem

Serial Interface Unit which supplies the Master Decommutator Unit with data input. The Master Decommutator Unit decommutates the input data, separating the Thematic Mapper data from the Multispectral Scanner data.

The MSS data from the Master Decommutator Unit is returned through another Serial Interface Unit to the Patch Panel Unit then to the High Density Data Recorder (HDDR) for recording. Data flow in this path is at 120 Mbps to the first Serial Interface Unit where the serial data is converted to an 8-bit bytes with an output rate of approximately 15 MBps. The Master Decommutator Unit strips out the MSS data and outputs it at a rate of 2 MBps to the MSS Serial Interface Unit. This unit operates in the "reverse direction", converting the 8-bit bytes to a serial bit stream at 16 Mbps. This data is routed through the Patch Panel Unit to the HDDR for recording. The tape on the HDDR will then contain only MSS data, plus the appropriate calibration information, station time, and predicted ephemeris.

In a similar manner the TM data is recorded, although the data rates are different. Output from the Master Decommutator Unit consists of 8-bit bytes at 15 MBps which when converted by the Serial Interface Unit back to serial format, results in a serial bit stream at 120 Mbps through the Patch Panel Unit to another HDDR. The TM data, calibration data, station time, and predicted ephemeris are then recorded.

Concurrently with the above, the TM data output from the Master Decommutator Unit is also supplied in 8-bit bytes to the Thematic Mapper Decommutator Unit which performs two separate processes. The Control Point Locator Unit requires information from one TM band which will subsequently be used to locate ground control points. The Thematic Mapper Decommutator Unit provides the single TM band data to the Control Point Locator Unit which, with computer input, searches for and locates the ground control points. This data is output to the Swath Correlator Unit as a fixed location, and then placed in disc memory for use in later data processing.

Simultaneously, the Thematic Mapper Decommutator Unit also outputs data from three selected TM spectral bands to the Cloud Cover Sampler Unit. The unit accepts these data and samples every tenth pixel on every twentieth line. (Selection of every twentieth

line insures that the same detector will always be used alleviating the need for radiometric correction at this point in the data system). Output from the Cloud Cover Sampler Unit is supplied to the Cloud Cover Analysis Unit which examines these data and determines the percentage cloud cover. The cloud cover so determined is referenced to the current time code received from the Time Code Channel Selector Unit and is output to the Swath Correlator Unit where it is linked with the control point locations and then recorded on disc for later data processing.

Each HDDR produces time code on an edge track and ephemeris data on another edge track. The Time Code Channel Selector Unit selects time code output from the appropriate HDDR, channels it through the Time Code Reader, and then to the Tape Scheduler Unit. Both the Time Code Reader and Tape Scheduler Unit are fully redundant and switched by controls from the Redundancy Management Unit. Output from the Tape Scheduler Unit provides routing commands to the Patch Panel Unit for all input signals and to the Tape Control Interface Unit which controls the complete operation of the four HDDR machines in this subsystem. Start and stop of each machine is automatically controlled to avoid gaps in recorded data; operator assistance is required only for tape loading and unloading, or when a tape breaks.

The DIS also contains an Archive Station Communication Unit (ASCU) which informs the Communication Management Unit about the current DIS status. When a tape recording is completed, the ASCU drives a Label Printer Unit which produces a label for the tape reel, annotated in readable type and also containing a wand-readable code number similar to those used for product identification in supermarkets. The label produced will be affixed to the tape reel by the operator, and then read by the wand to verify the label number to the Communications Management unit. This procedure then places in the Communications Management unit the fact that the data was recorded, where the tape is located physically, and what its number code is. Wherever that tape is located in the ground system after that point in time, reading of the label with a wand will inform the Communications Management Unit of the current recording location, preventing any lost tapes.

A teletype terminal and hard copy printer are also a part of the DIS for input from the operator to the Communications Management Unit of any additional data concerning the tape, data on it, or unusual circumstances.

4.3 THE CENTRAL DATA PROCESSING FACILITY (CDPF)

The Central Data Processing Facility (CDPF) accepts input data on High Density Digital Tapes, converts the serial bit stream to 8-bit bytes in a Serial Interface Unit and performs data reformatting in the Line Commutator Unit, changing the data format from band-sequenced-by-detector to band-interleaved-by-line. This rearranged data is then processed in the Radiometric Corrector Unit which utilizes the standard radiometric correction algorithms developed by NASA.

The radiometrically corrected data then drives a Video Terminal Unit (VTU) for operator observation, and another SIU which converts the 8-bit bytes back into a serial 120 Mbps data flow. These data are routed back through the Patch Panel Unit (PPU) to another High Density Digital Tape Recorder (HDDR).

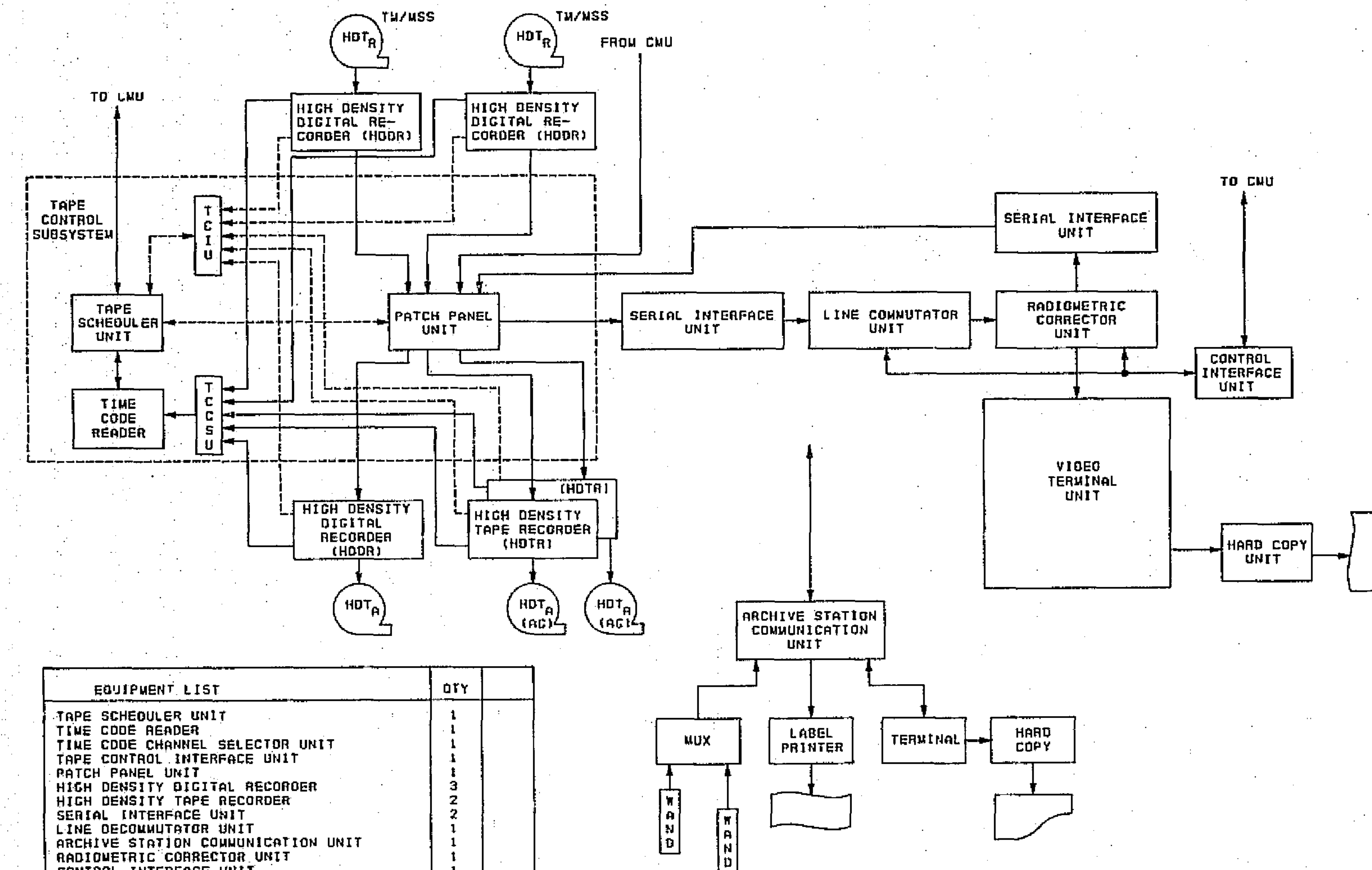
Signal flow for the above can be observed in Figure 4-3 The Central Processing Data Facility. . Other elements of the subsystem are relatively straightforward, operating at data rates of 15 Mbps. The radiometric correction is done in a "pipeline" fashion which eliminates the rather extensive system timing problem which would be formidable otherwise.

4.4 THE PRODUCT GENERATION AND DISSEMINATION FACILITY (PGDF)

4.4.1 GEOMETRIC CORRECTION SUBSYSTEM

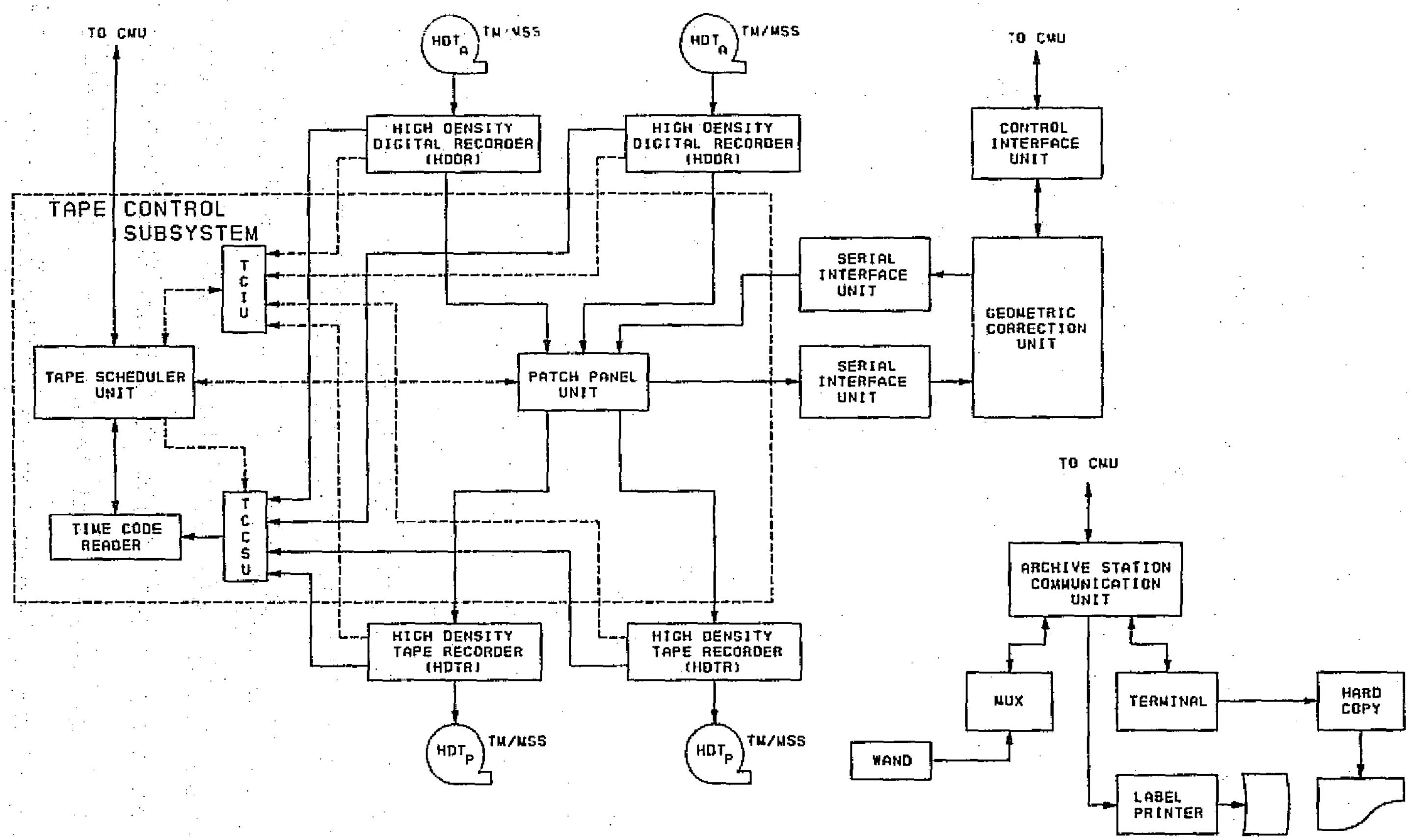
The basic, working part of this subsystem is the Geometric Corrector Unit. The balance of the units comprising the subsystem are simply interface devices with this unit.

Information flow through the Geometric Correction Subsystem begins with the input tape being played back on the High Density Recorder (HDDR) as shown in Figure 4-4. Data and time code information are input to the Tape Control Subsystem, providing commands to the Patch Panel Unit, the recorders, and back to the Communication



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TIME CODE READER	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
HIGH DENSITY DIGITAL RECORDER	3	
HIGH DENSITY TAPE RECORDER	2	
SERIAL INTERFACE UNIT	2	
LINE DECOMMUTATOR UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	
RADIOMETRIC CORRECTOR UNIT	1	
CONTROL INTERFACE UNIT	1	
VIDEO TERMINAL UNIT	1	
HARD COPY UNIT	1	

Figure 4-3. The Central Data Processing Facility



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TIME CODE READER	1	
HIGH DENSITY DIGITAL RECORDER	2	
HIGH DENSITY TAPE RECORDER	2	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	2	
GEOMETIC CORRECTION UNIT	1	
CONTROL INTERFACE UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 4-4. The Geometric Correction Subsystem

Management Unit. The serial data stream is converted to 8-bit bytes in the Serial Interface Unit, and the data is then ready to enter the Geometric Correction Unit.

Commands to the Geometric Correction Unit are received from the Communications Management Unit by the Control Interface Unit. Data output from Geometric Correction Unit is reconverted to a serial bit stream by another Serial Interface Unit and then routed through the Patch Panel Unit to the High Density Tape Recorder (HDTR) for recording.

The Geometric Correction Subsystem also communicates with the Communication Management Unit through an Archive Station Communication Unit. This unit generates the labels for the output tape reels, provides the means for reading the labels (the optical wand unit), and provides a terminal unit for operator and system input/output at the Geometric Correction Subsystem location.

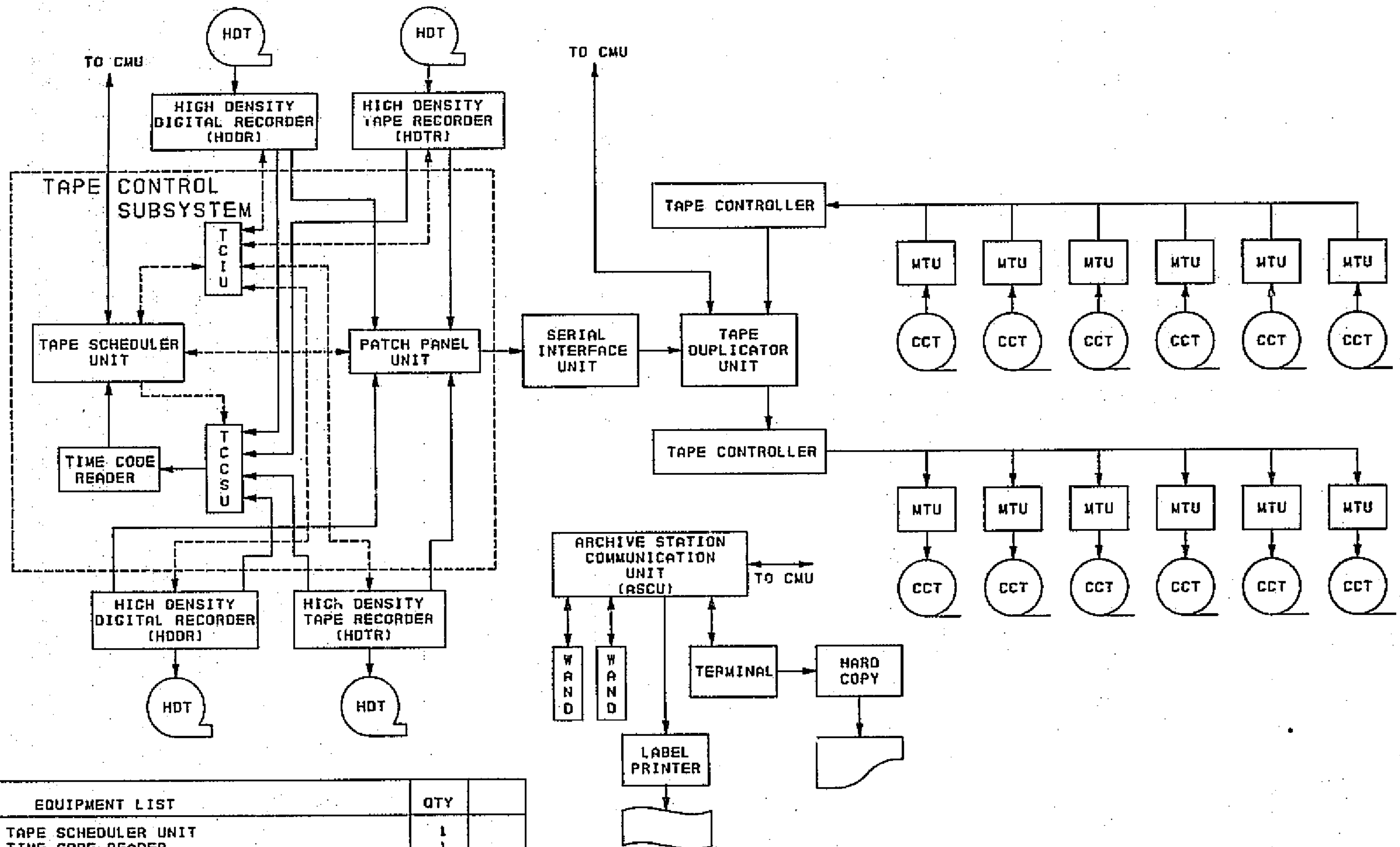
4.4.2 TAPE DUPLICATION SUBSYSTEM

The Tape Duplication Subsystem, shown in Figure 4-5, accepts data input in HDDR or HDTR system tape media and converts it to suitable input to the Magnetic Tape Units for the generation of Computer Compatible Tapes (CCT). The Tape Duplication Subsystem can also duplicate the original HDDR or HDTR input tape, or duplicate a CCT. Control of the subsystem comes from the Communication Management Unit and is based upon copy requests submitted from various users.

The Tape Duplication Subsystem also provides tape identification through a word label reader and the Archive Station Communication Unit. Once an input tape is identified, control commands from the Communications Management Unit set up and initiate the duplication process. The label printer produces appropriate labeling for the output tapes.

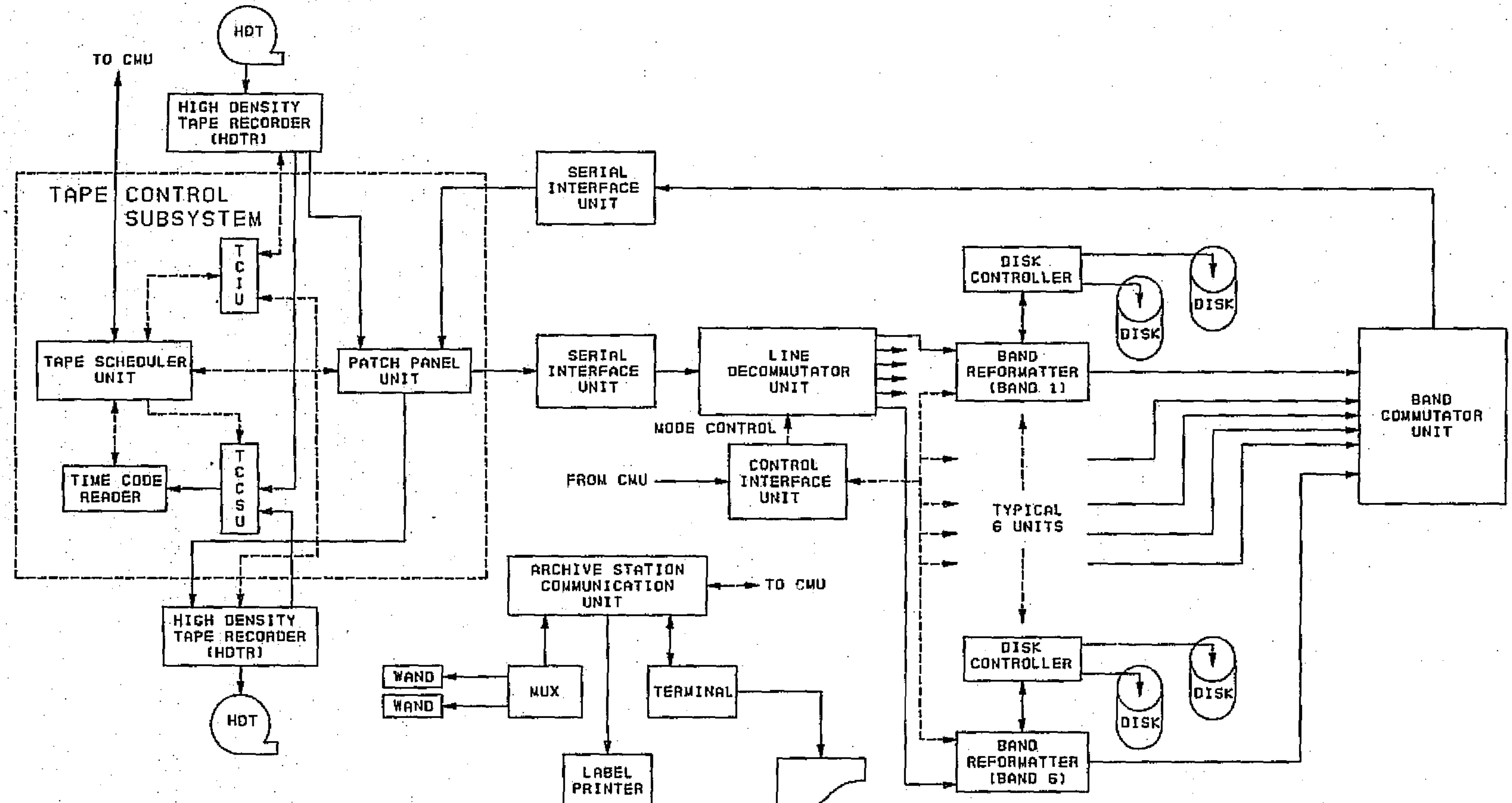
4.4.3 TAPE REFORMATTER SUBSYSTEM

Data input and output from the Tape Reformatter Subsystem is controlled by the Tape Control Subsystem under instructions received from the Communication Management Unit, as shown in Figure 4-6. Data flow, sequence of operations, and time code processing are performed and/or controlled by this unit. Input data after routing in the Tape Control



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TIME CODE READER	1	
TIME CODE CHANNEL SELECT UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	1	
HIGH DENSITY DIGITAL RECORDER	2	
HIGH DENSITY TAPE RECORDER	2	
TAPE DUPLICATOR UNIT	1	
TAPE CONTROLLER	2	
MAGNETIC TAPE UNIT	12	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 4-5. The Tape Duplication Subsystem



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TIME CODE READER	1	
TIME CODE CHANNEL SELECT UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
HIGH DENSITY TAPE RECORDER	2	
SERIAL INTERFACE UNIT	2	
LINE DECOMMUTATOR UNIT	1	
BAND COMMUTATOR UNIT	1	
CONTROL INTERFACE UNIT	1	
BAND REFORMATTER UNIT	6	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 4-6. The Tape Reformatter Subsystem

Subsystem is processed by a Serial Interface Unit and then fed into the Line Decommutator Unit. This unit separates band interleaved data (interleaved line-by-line), to separate lines in each band. Each band output is then stored on disc, and output to the Band Commutator Unit in a band-sequential format. The Band Commutator Unit recommutates the data, which passes through another Serial Interface Unit, converting the data back into serial format. It then enters the Tape Control Subsystem and is recorded on a HDTR.

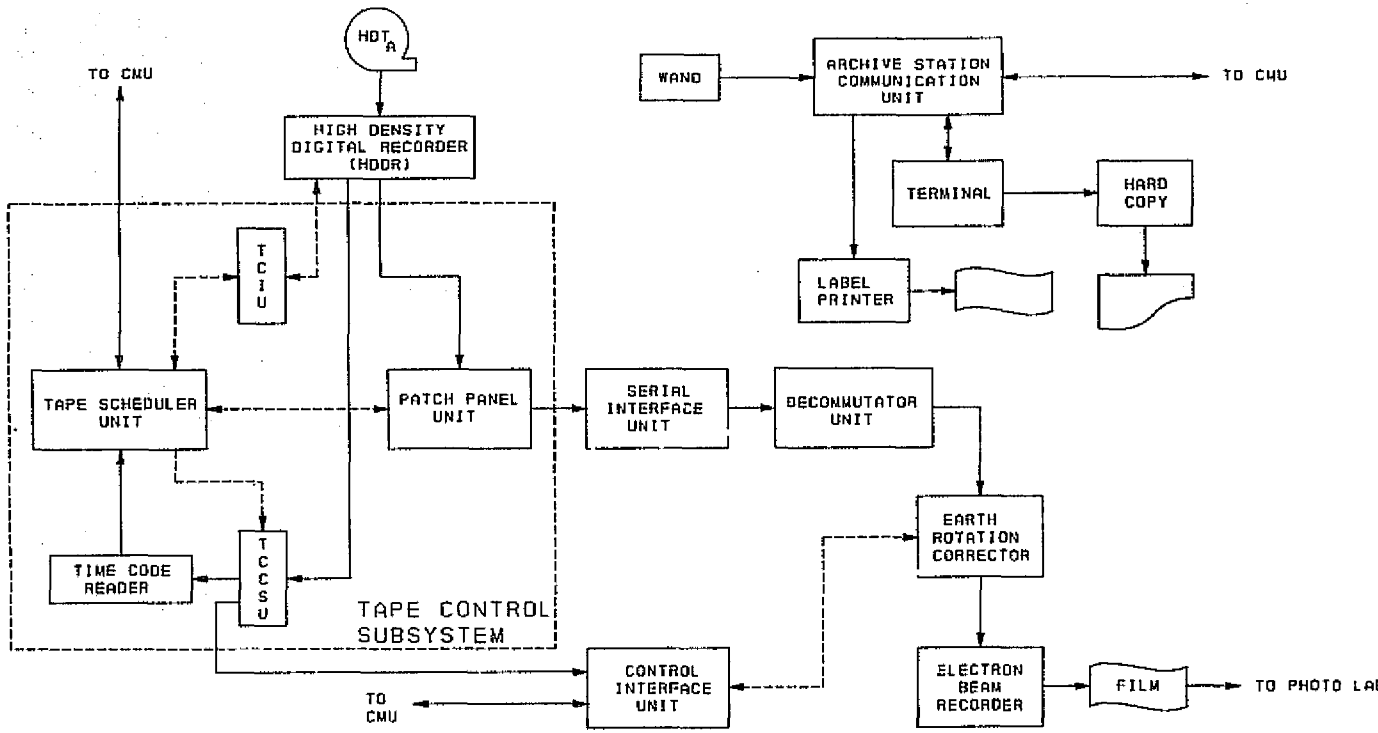
4.4.4 BROWSE GENERATOR SUBSYSTEM

The Browse Generator Subsystem converts tape recorded data to photographic film images, corrected for earth rotation effects, and outputs them for scene quality assessment and generation of scene "shopping lists". Data input to Browse Generation Subsystem is through a Tape Control Subsystem which provides interaction/control from the Communications Management Unit as shown in Figure 4-7. Serial output data from the HDDR is routed through a Serial Interface Unit, where it is converted to 8-bit bytes, and through a decommutator in order to select pixels from the desired spectral band. Spacecraft location is provided by Communications Management Unit to a Central Interface Unit which establishes the amount of correction required for earth rotation. The data is then modified to correspond to this, and converted to latent film imagery by the Electron Beam Recorder.

4.4.5 THE FILM GENERATOR SUBSYSTEM

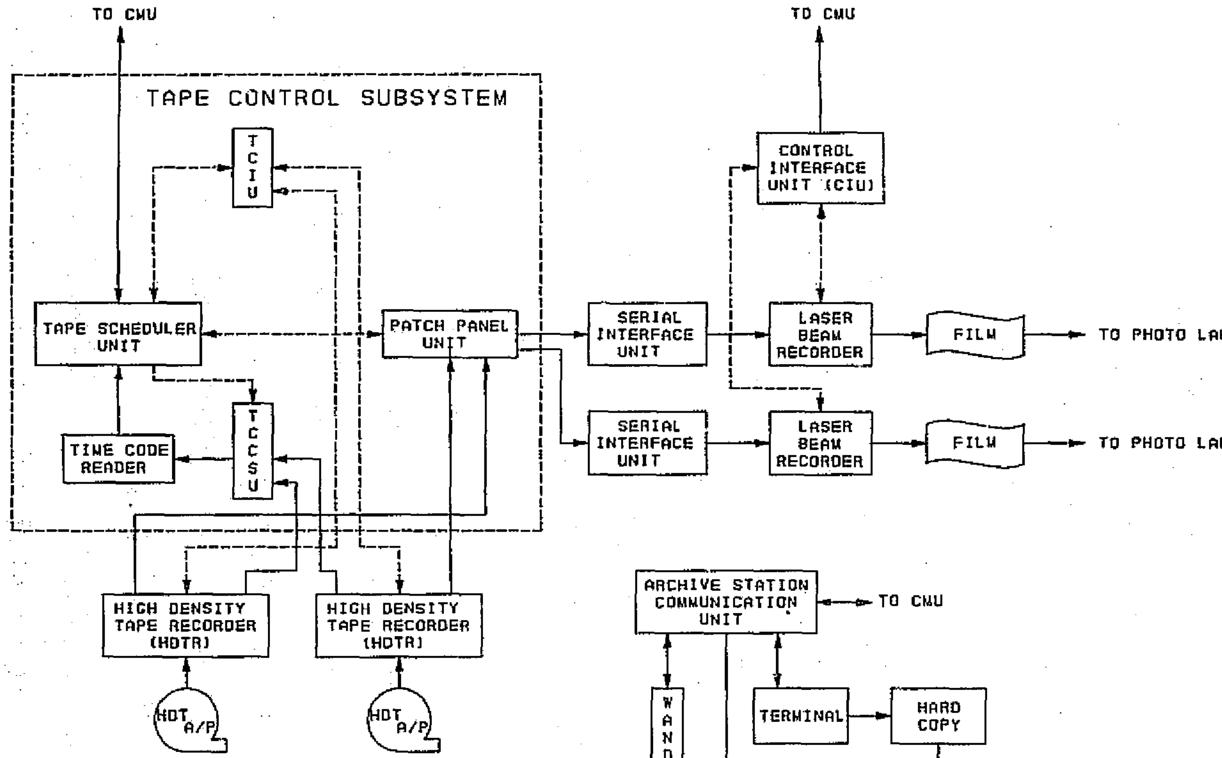
The Film Generator Subsystem accepts data tapes as input and processes them under Communications Management Unit control into latent image output (See Figure 4-8). Input data is routed through a Serial Interface Unit where it is converted into 8-bit bytes. This data provides the driving signal to a Laser Beam Recorder which produces high quality, high resolution latent imagery on photographic film. Annotation of the imagery with sensor/satellite/time/etc. information is also provided to the recorder.

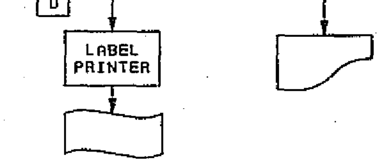
All operational commands to the Film Generator Subsystem originate in the Communications Management Unit and are started when the input tape reel label is read by the band input device in the Film Generator Subsystems' Archive Station Communication Unit.



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECT UNIT	1	
TIME CODE READER	1	
HIGH DENSITY DIGITAL RECORDER	1	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	1	
CONTROL INTERFACE UNIT	1	
DECOMMUTATOR UNIT	1	
EARTH ROTATION CORRECTOR	1	
ELECTRON BEAM RECORDER	1	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 4-7. The Browse Generator Subsystem



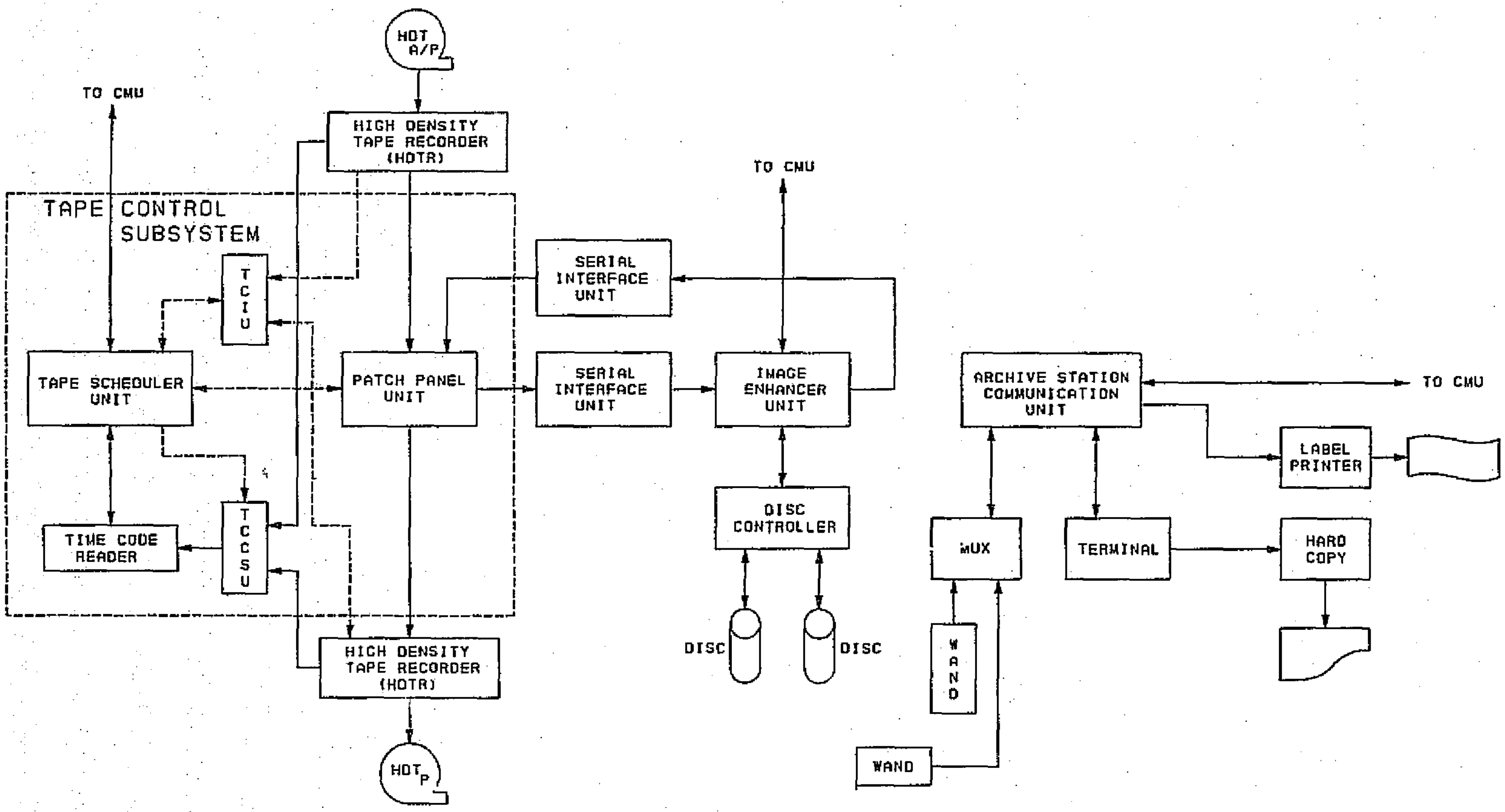


EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TIME CODE READER	1	
HIGH DENSITY TAPE RECORDER	2	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	2	
LASER BEAM RECORDER	2	
ARCHIVE STATION COMMUNICATION UNIT	1	
CONTROL INTERFACE UNIT	1	

Figure 4-8. The Film Generator Subsystem

4.4.6 THE IMAGE ENHANCER SUBSYSTEM

The Image Enhancer Subsystem provides the capability to perform image enhancements for non-standard image products. The subsystem is shown in Figure 4-9. Typical of the class of enhancements are "gamma compensation", "level slicing" and digital filtering . Requests for special enhancement products are handled by the DMS in a manner similar to normal product requests, in that requests are received by the Data Management Unit from the Local Transaction Unit or the External Transaction Unit. The Data Management Unit then schedules the processing and issues a tape retrieval request to the archive via the proper Archive Station Communication Unit. Once the archival input tape is mounted and registered, the Data Management Unit will issue a process request to the Image Evaluation Subsystem and monitor the status of the output tape product.



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TIME CODE READER	1	
HIGH DENSITY TAPE RECORDER	2	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	2	
IMAGE ENHANCER UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 4-9. The Image Enhancer Subsystem

SECTION 5

ALTERNATE DESIGN CONCEPTS

The previous sections of this report have focused on a "full up" version of the Data Processing Facility. This system design satisfies the entire spectrum of requirements initially defined for the Landsat D mission. It is capable of receiving the full data stream from two spacecraft, via TDRSS, applying edit criteria (in the DIS) and processing approximately 500 Thematic Mapper scenes per day. In addition to the Thematic Mapper data the system will handle the Multispectral Scanner, MSS, data and its processing as well. The cost estimates corresponding to this "full up" design option are presented in the following section.

As this Data Processing Facility study progressed, some of the basic concepts relating to the Landsat D mission were modified. This section will reflect some of these changes as they manifested themselves in the ground system design. These mission changes and the alternate system they begot occurred late in the study cycle and thus the alternate system was not developed in as great a detail as the initial "full up" option.

The basic Landsat D principles adapted for the alternate system, referred to as the "baseline" option, are summarized as:

- one Landsat D spacecraft in orbit (not two)
- The CDPF will be located at GSFC (not at White Sands, New Mexico)
- The major user interface functions will be provided by the EROS Data Center (EDC) at Sioux Falls
- The MSS data will be decommutated from the data stream and processed by the GSFC NASA Data Processing Facility (NDPF) with the Master Data Processor (MDP)
- Approximately 100 Thematic Mapper scenes per day will be processed by Landsat D (not the approximately 500/day of the "full up" option).
- This "baseline" option will provide the basic structure to enable later growth to the "full up" option if the requirements should change.
- The focus for user services and product order origination will be the EDC at Sioux Falls, not the Landsat D system.

- Only a very nominal capability will be provided for the generation of TM based film products.

In terms of the major subsystems of the Data Processing Facility, these modified mission requirements are reflected as follows:

DIS (Data Input Subsystem) - The DIS would remain largely the same. It would still record the data, perform cloud cover assessment and scene editting, and compute geometric corrections on a per swath basis. Some reduction in tape recorders and operating personnel would be realized.

CDPF (Central Data Processing Facility) - The CDPF would be located at GSFC and would make extensive use of existing facilities. The MDP would still be used to process MSS data. A radiometric corrector/reformatter would be installed to handle TM data.

PGDF (Product Generation and Dissemination Facility) - This subsystem is one of the bigger changes. The present EROS data center will be employed to perform all product generation and dissemination activities. The only additional equipment required would be a scene reformatter, some tape recorders, etc. The Electronics Data Image Processing System, EDIPS, will be used to perform any required corrections and the film recorders in place would suffice.

DMS (Data Management Subsystem) - The DMS as described in Section 4.1 would be modified. Portions of the Redundancy Management Subsystem and some overall system management and communication will be eliminated. There also would be additional costs of DOMSAT links, DOMSAT ground stations and additional supporting equipment which would be necessary to transmit the data from facility to facility.

This system would involve a minimum initial outlay but would be amenable to growth once the anticipated demand for TM scenes is realized.

It should be noted that although the cost of this reduced system is considerably lower (see section 6.0 System Costs) a significant reduction in system capability has also resulted. The most noticeable reduction is in scenes/day which have been reduced from the 438 of the system design to 50-100. Less obvious, but perhaps more significant, was the elimination of overall ground system capability such as: system redundancy and redundancy management, reduction of the capability in the PGDF to process TM tapes,

the delegation of MSS data to the existing system of today, and a reduction in overall system data management. Finally, the decentralization of the ground system into discrete subsystems in separate physical locations establishes barriers to growth toward an efficient, operational full-up system.

The system block diagrams for the "baseline" design option are presented in figures 5-1 through 5-7. The figure numbers and the corresponding subsystems (similar to those for the "full up" option shown in Section 4) are:

The cost estimates for this "baseline" design option are presented in Section 6.

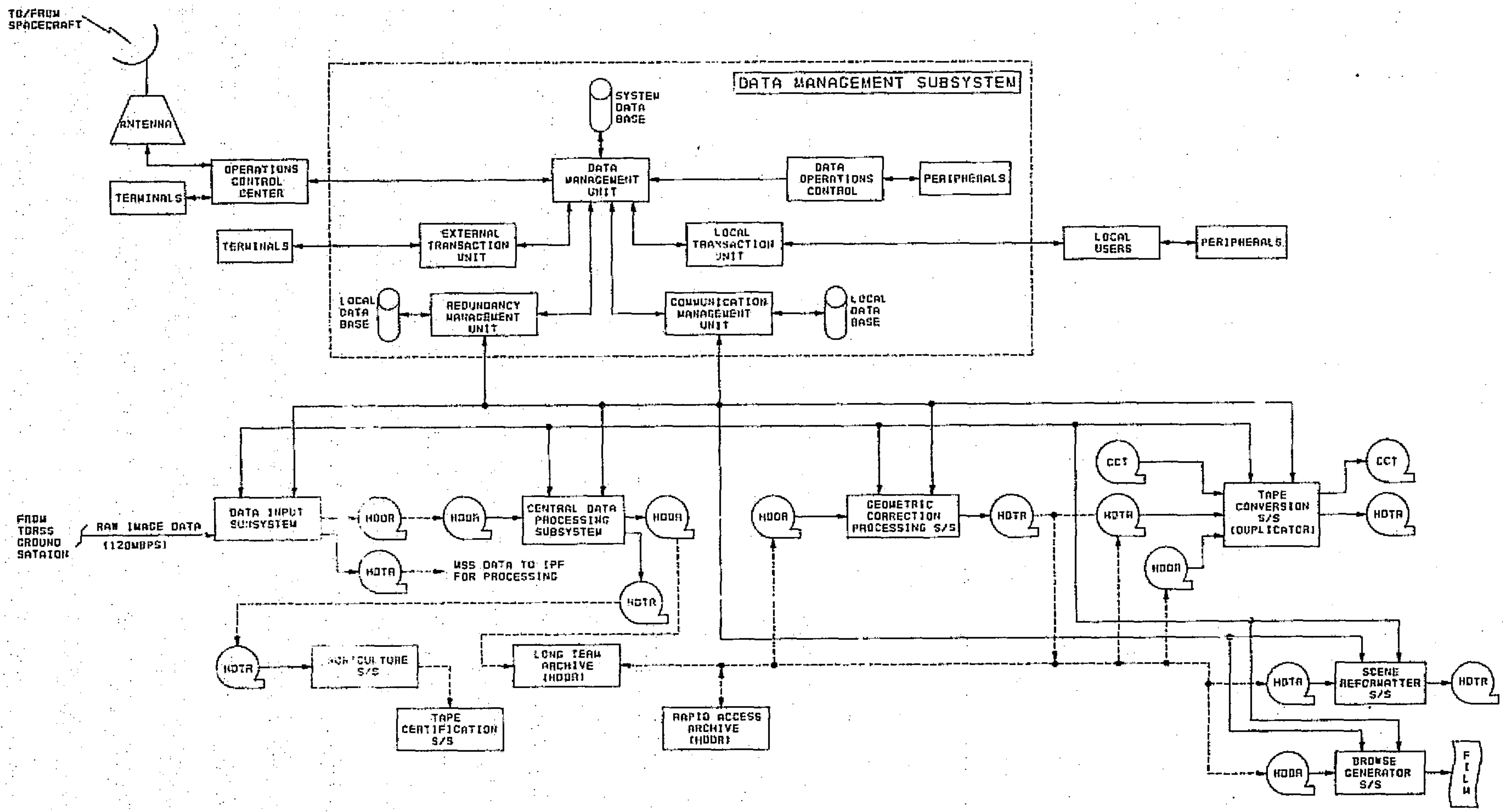


Figure 5-1 Overall System Block Diagram (Baseline)

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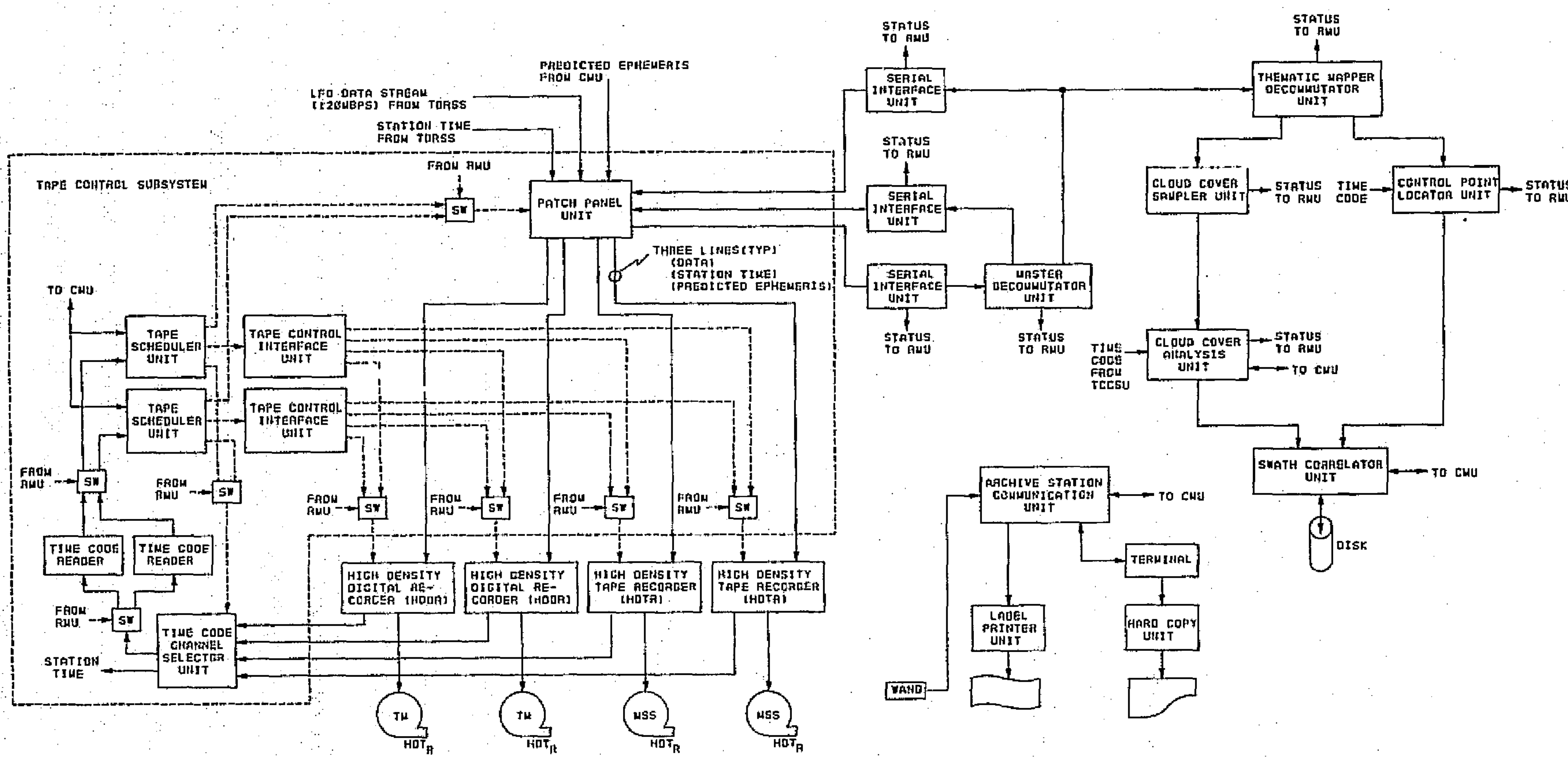
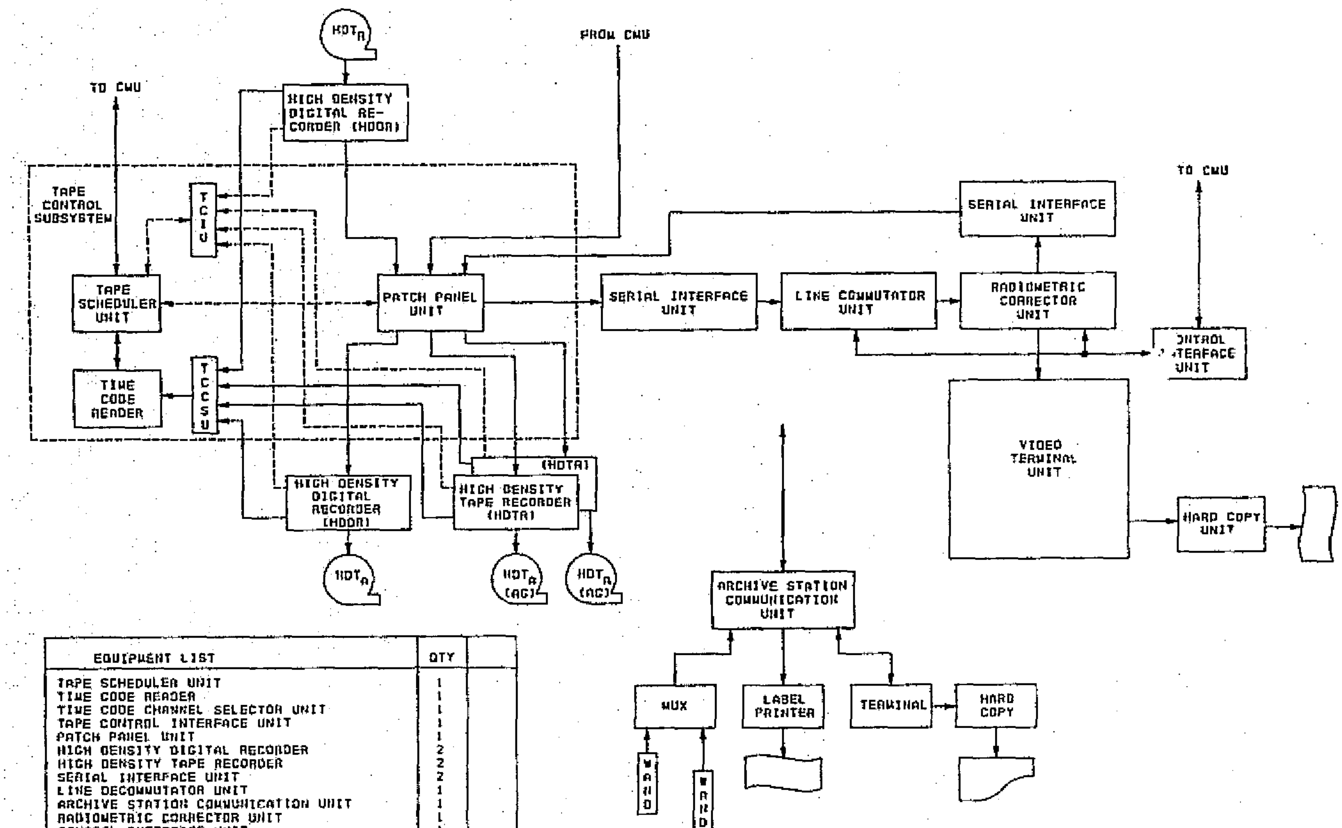


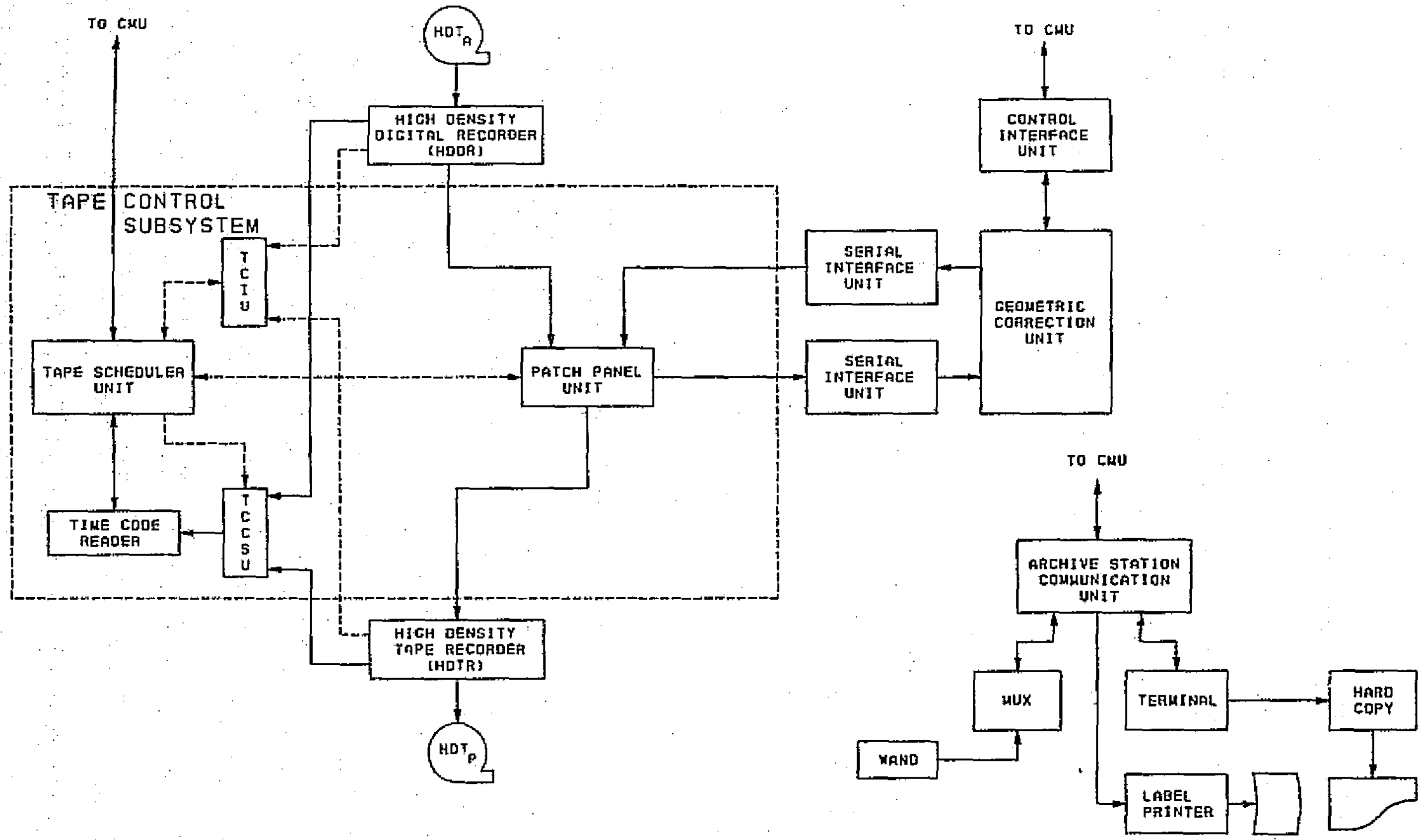
EQUIPMENT LIST	QTY	
TAPE CONTROL I/F UNIT	2	
TAPE SCHEDULER UNIT	2	
TIME CODE READER	2	
TIME CODE CHANNEL SELECTOR UNIT	1	
HIGH DENSITY DIGITAL RECORDER	2	
HIGH DENSITY TAPE RECORDER	2	
PATCH PANEL UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	
SERIAL INTERFACE UNIT	3	
MASTER DECOMMUTATOR UNIT	1	
TM DECOMMUTATOR UNIT	1	
CLOUD COVER SAMPLER UNIT	1	
CLOUD COVER ANALYSIS UNIT	1	
SWATH CORRELATOR UNIT	1	
CONTROL POINT LOCATOR UNIT	1	
CONTROL PATH SWITCHES	7	

Figure 5-2 Data Input Subsystem -- DIS (Baseline)



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TIME CODE READER	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
HIGH DENSITY DIGITAL RECORDER	2	
HIGH DENSITY TAPE RECORDER	2	
SERIAL INTERFACE UNIT	2	
LINE DECOMMUTATOR UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	
RADIOMETRIC CORRECTOR UNIT	1	
CONTROL INTERFACE UNIT	1	
VIDEO TERMINAL UNIT	1	
HARD COPY UNIT	1	

Figure 5-3 Central Data Processing Facility -- CDPF (Baseline)



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECTOR UNIT	1	
TIME CODE READER	1	
HIGH DENSITY DIGITAL RECORDER	1	
HIGH DENSITY TAPE RECORDER	1	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	2	
GEOMETIC CORRECTION UNIT	1	
CONTROL INTERFACE UNIT	1	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 5-4 Product Generation & Dissemination Facility --PGDF Geometric Corrector Subsystem (Baseline)

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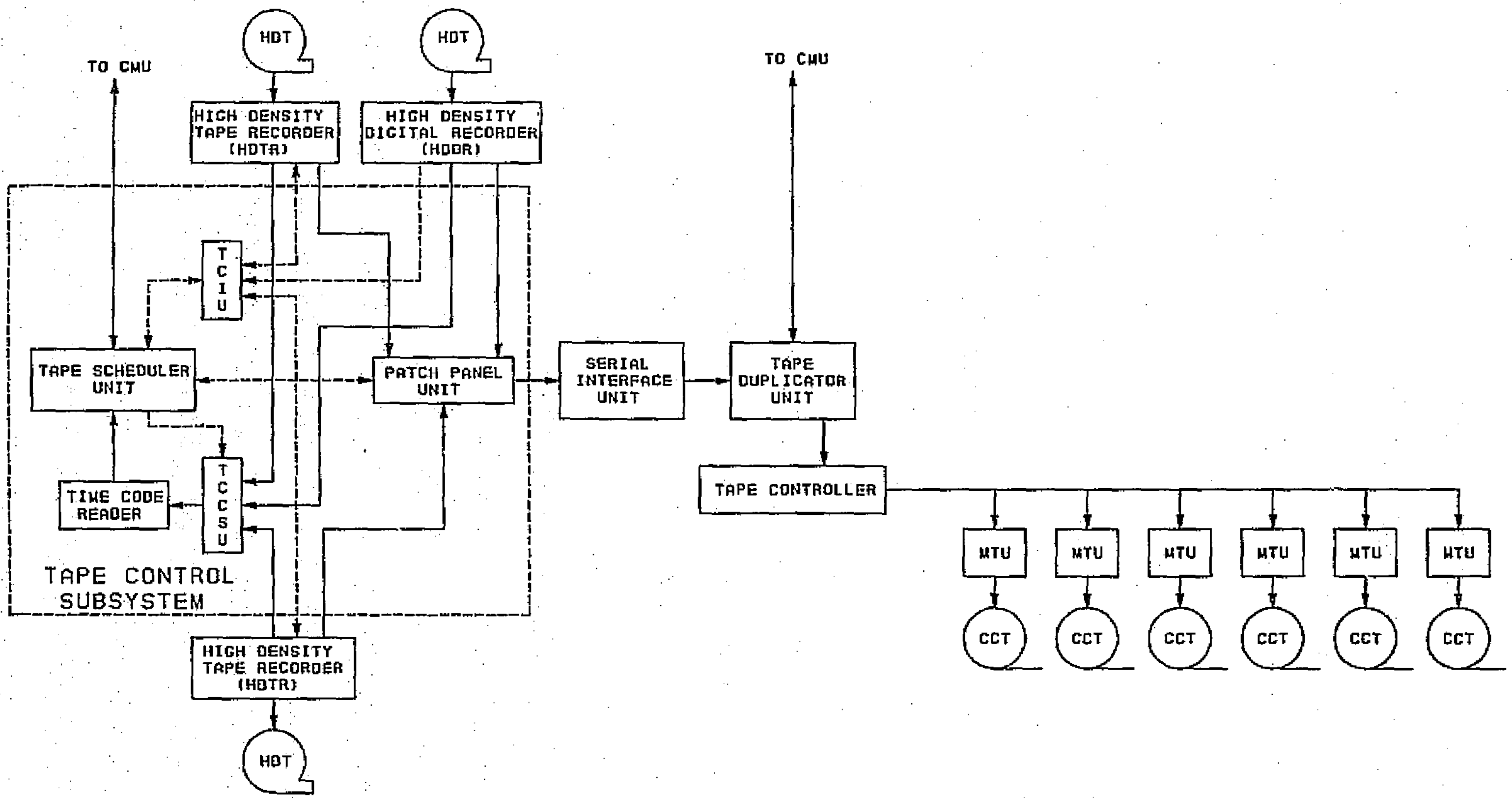

EQUIPMENT LIST	QTY	
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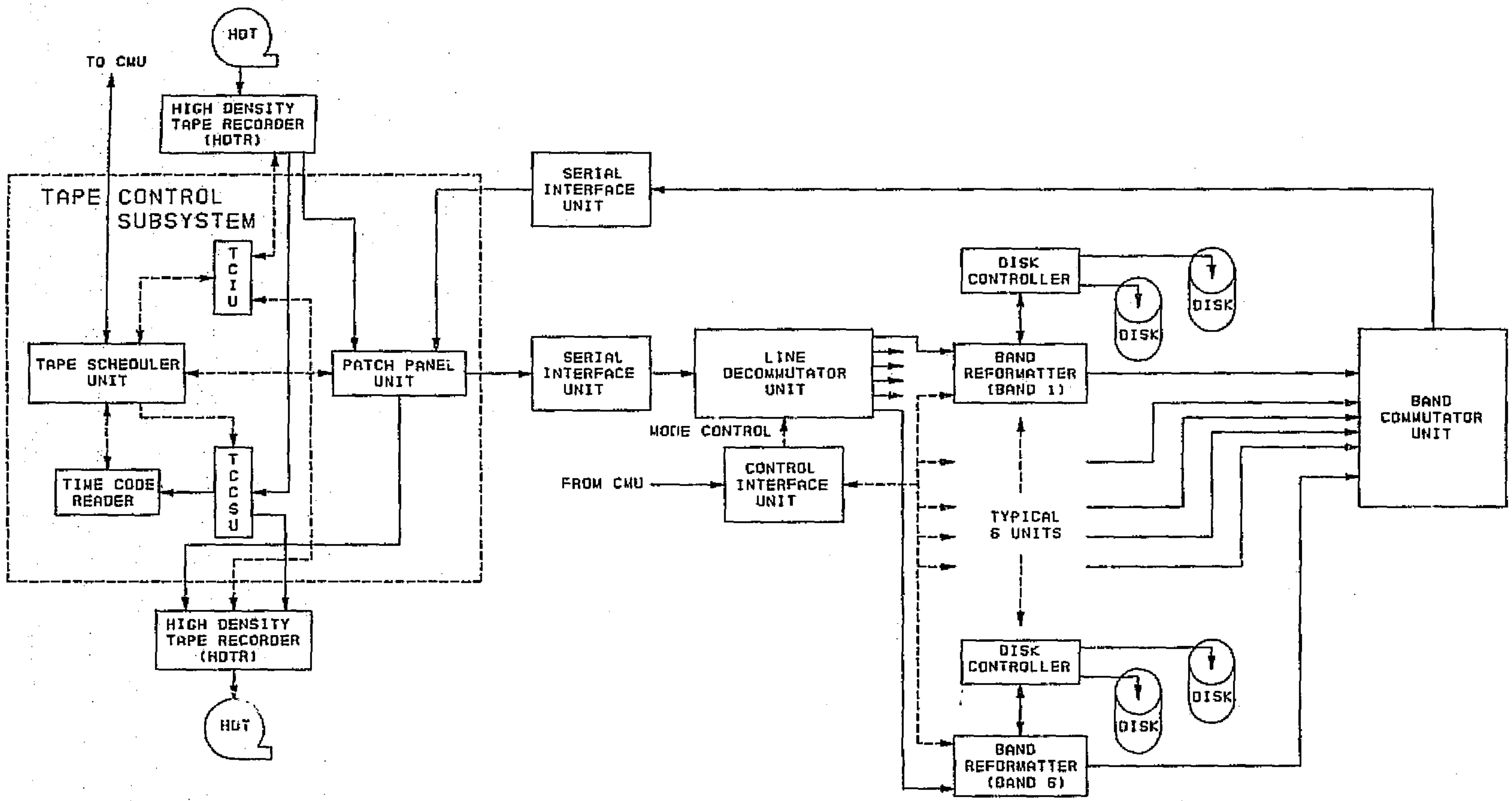
TIME CODE READER	1	
TIME CODE CHANNEL SELECT UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	1	
HIGH DENSITY TAPE RECORDER	2	
HIGH DENSITY DIGITAL RECORDER	1	
TAPE DUPLICATOR UNIT	1	
TAPE CONTROLLER	1	
MAGNETIC TAPE UNIT	6	

Figure 5-5 PGDF -- Tape Duplicator Subsystem (Baseline)



EQUIPMENT LIST	QTY	
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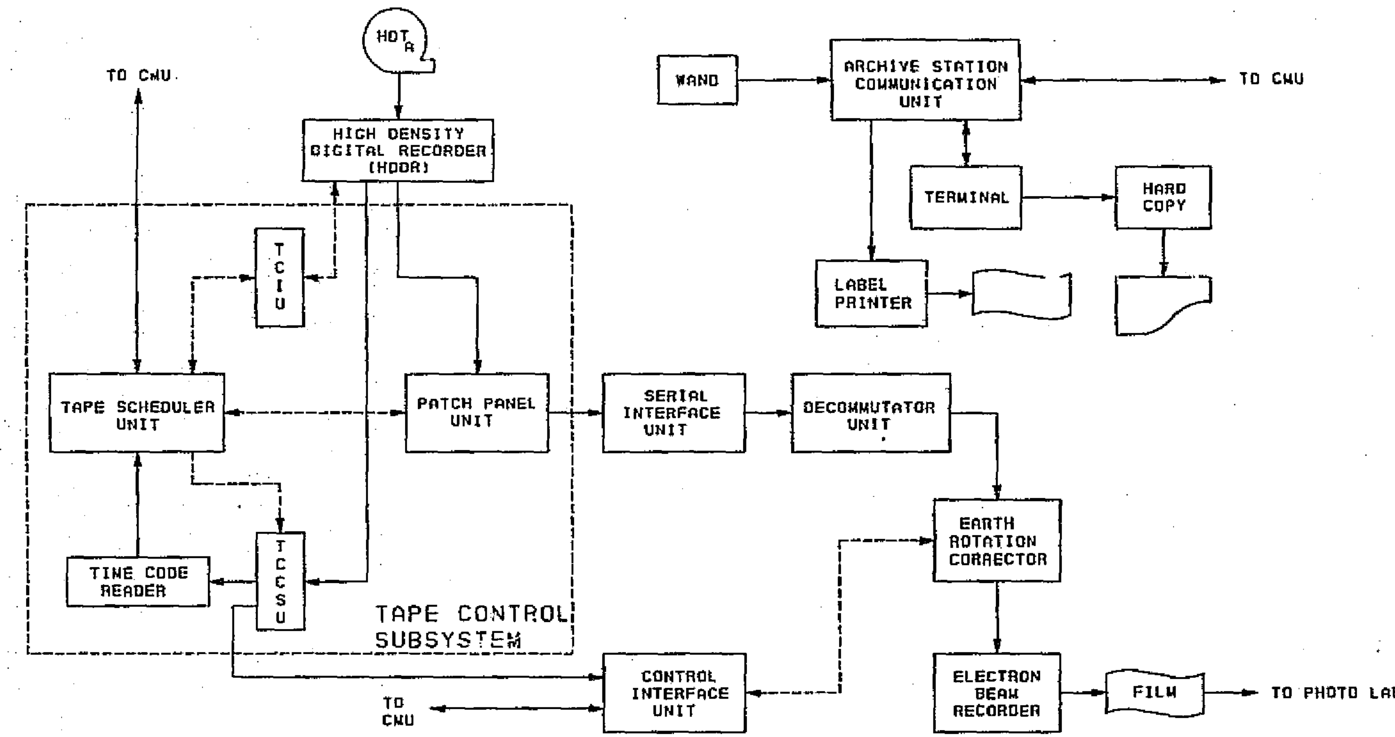
TIME CODE CHANNEL SELECT UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
PATCH PANEL UNIT	1	
HIGH DENSITY TAPE RECORDER	2	
SERIAL INTERFACE UNIT	2	
LINE DECOMMUTATOR UNIT	1	
BAND COMMUTATOR UNIT	1	
CONTROL INTERFACE UNIT	1	
BAND REFORMATTER UNIT	6	

Figure 5-6 PGDF -- Tape Reformatter Subsystem (Baseline)



EQUIPMENT LIST	QTY	
TAPE SCHEDULER UNIT	1	
TAPE CONTROL INTERFACE UNIT	1	
TIME CODE CHANNEL SELECT UNIT	1	
TIME CODE READER	1	
HIGH DENSITY DIGITAL RECORDER	1	
PATCH PANEL UNIT	1	
SERIAL INTERFACE UNIT	1	
CONTROL INTERFACE UNIT	1	
DECOMMUTATOR UNIT	1	
EARTH ROTATION CORRECTOR	1	
ELECTRON BEAM RECORDER	1	
ARCHIVE STATION COMMUNICATION UNIT	1	

Figure 5-7 PGDF -- Browse Generator Subsystem (Baseline)

SECTION 6

COST ESTIMATES

As part of this study it was required to provide Rough-Order-of-Magnitude (ROM) cost estimates of the recurring and non-recurring costs of the Data Processing Facility System. The purpose of these cost estimates is their intended use in developing a total (spacecraft and ground) cost/benefit economic analysis as well as for their use by NASA in budgetary planning.

Econometric models have been developed which provide estimates of the economic benefit expected to accrue to the United States from the implementation of various remote sensing based application missions. In most cases these benefits are based on an increased or new mission capability which is provided or enabled through the use of remote sensing. The benefits associated with this incremental increase (over the existing or alternative mission) in mission capability must of course be compared with the incremental costs necessary to achieve the improved capability.

Although every effort was made to make these cost estimates as accurate as possible, it must be remembered that these are only ROM estimates to be used for budgetary and planning purposes. The cost estimates are, of course, directly related to the system requirements and resulting design upon which they are based. As the mission becomes better understood, and the requirements more definitive, it is expected that the costs will change from these initial estimates.

6.1 COST ESTIMATING GROUNDRULES AND ASSUMPTIONS

The following groundrules and assumptions were adopted during this study for purposes of arriving at the cost estimates. They are an integral part of the resulting ROM estimates and should be reviewed closely.

1. An average labor rate of $48K per year through overhead and G&A (and before fee and contingency) was used for each applied man throughout the design, fabrication, and test phases of the program. This value represents a reasonable mean between the higher paid senior engineers/managers and the lesser paid technicians/shop personnel.

2. Field rates were used for estimating the cost of training operators and for the recurring station operations. These rates were supplied by NASA/GSFC and are as follows through overhead and G&A per year.

o Managers/Engineers/Supervisors	$36.36K
o Lead Technicians/Operators	$23.64K
o Clerical and Support	$13.64K

3. Overhead, IR&D, and General and Administrative rates are included as appropriate in each of the above man-year labor rate categories (direct and field support). The inclusion of these makes the labor rates used fully burdened and thus they only require the final addition of a contingency factor and profit (or fee).

4. Costs were included for contract support and similar support activity, in addition to the basic catalog price for all purchased items.

5. All costs provided are in basic 1976 dollars; no forward pricing or inflation factors were used in these estimates.

6. Where newly designed items are used in more than one subsystem of the Landsat D ground system, the engineering design and drafting costs (non-recurring) were only costed once.

7. Published catalog prices were used for estimating purchased hardware and software whenever possible; in a few cases it was necessary to rely on engineering estimates and past experience for estimates of these purchased items.

8. The cost estimates presume the use of a private (for profit) contractor for all items and include provision for fee or profit at the rate of 10% on total cost.

9. No provision in the cost estimates is made for the physical facilities, land, security, nor operational utilities (light, power, heat, etc.); all of these are assumed to be provided by the government at no explicit cost to the project.

10. A contingency factor of 10% is included in the final total cost to account for some flexibility in requirements growth and unanticipated cost items.

11. No provision was included in the cost estimate for a warranty or guarantee beyond system acceptance. Any warranty or service contract of this type would be additional.

6.2 COST BREAKDOWN STRUCTURE

The cost estimates for the Data Processing Facility were derived from a "bottoms-up" analysis of each cost element. A cost breakdown structure was developed to four levels of depth as shown in Figure 6-1. Included on this figure are the major task elements which constitute the cost elements. The following descriptions summarize the third level of the cost breakdown structure.

1. System Engineering - this element provides for the overall design definition and integration of the various subsystem elements. Design reviews are provided for and the performance requirements are established.

2. Equipment Design and Fabrication - this element accumulates the cost of equipment design and manufacture. Purchase of material and bought components; the detailed electrical, mechanical, and packaging design; the necessary drafting and analysis support; and special test equipment design are all included in this cost element.

3. Software Design and Test - because of the importance of software as a key element in digital systems it has been given particular visibility. Included are both the software design and software test activities.

4. System Integration and Test - provides for the subsystem and system level tests of the integrated components. This is representative of the final test at the contrac- tractors facility prior to the shipping of equipment to the installation site.

5. Site Installation and Checkout - includes the actual shipment of equipment to the operational site as well as the performance of the final acceptance test on the system.

6. Personnel Training - a training course will be conducted to train the on-site field personnel who will operate and maintain the system.

7. Program Management - provides for the overall management and control of the entire systems development activity. Program management, administrative, and clerical support are included as well as providing for reports and communication with the customer.

8. Station Operations - this cost element provides for the yearly recurring costs which begin following the final acceptance test. The principal cost here is that of the on-site field personnel responsible for operating ar' maintaining the system. Costs are also included for expendable and consumable material items as well as for replacement spare parts.

6.3 COST ESTIMATING PROCEDURE

A "bottoms-up" cost estimating approach was used to estimate each of the various cost elements in the cost breakdown structure. In all cases the initial engineering and manufacturing cost estimates were reviewed by three levels of management to ensure their accuracy and consistency with recent experience. The following paragraphs are intended to provide some understanding of the rules-of-thumb applied and the procedures followed.

For each of the subsystems, a parts list was developed with each part identified and costed. A percentage was added to the catalog price of purchased items for the contract support required to generate the documentation and provide the necessary controls to purchase all buy items. The cost of the materials required for the newly designed items was estimated based on experience with similar items developed for previous ground stations. The labor effort required to design and manufacture the make items, and to provide the necessary design and manufacturing effort to develop the source control drawings, procurement specifications, and to assemble the buy items, were also estimated based on experience gained with similar equipment.

Catalog prices were used for all purchased items. The labor effort required for the design, drafting, and manufacturing of new items was based on experience with similar equipment, with appropriate complexity factors to adjust the total cost. Material costs were basedon the number of electronic circuit boards, the number of parts per board, etc. The systems engineering task was costed based on a level of effort across the two (2) year assumed program duration.

Ten (10) percent of the total material dollars were added to account for non-recurring spares. No specific analysis was conducted as to the detailed repair and replacement level nor were particular equipments identified for sparing. Rather, the 10% rule-of-thumb was applied across the board.

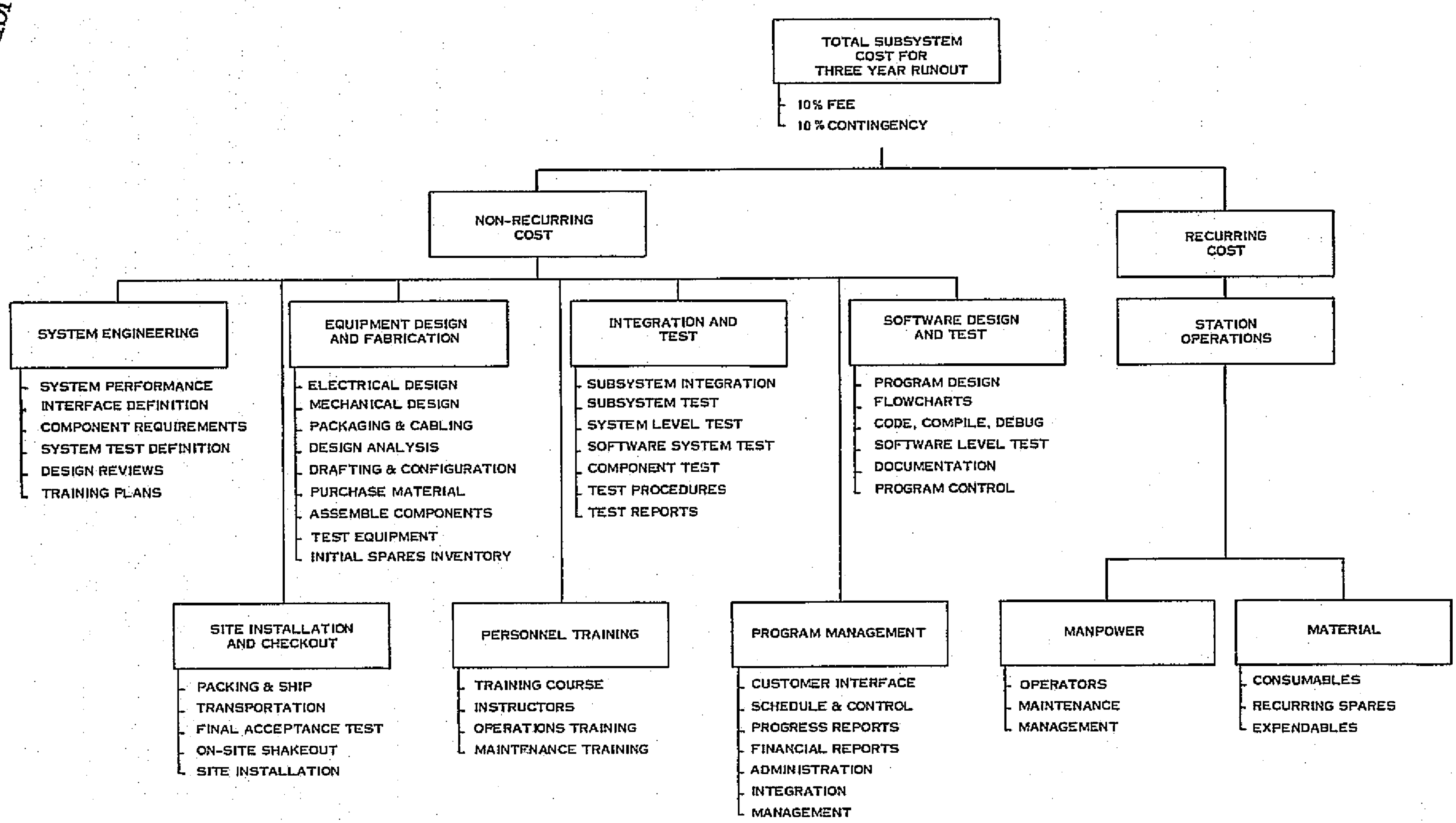


Figure 6-1. Cost Breakdown Structure

Catalog prices were used for all purchased software packages. The labor required to design the operational and test software, and to perform the debug and verification, was based on experience with similar software systems developed on previous programs and adjusted according to their relative complexities.

The System Integration and Test task was costed by estimating the number of people required to conduct and operate the particular subsystem equipment over the integration and test period.

The cost to pack and ship each subsystem was based on the number of equivalent single bay racks weighing approximately 800 pounds each. Each rack would be supported on a skid (100 pounds each) and the cost for shipping is approximately $20 per 100 pounds. The installation and acceptance test efforts were costed based on the estimated number of men required over the given installation and test periods.

This task was costed by estimating the number of operators to be trained along with their associated labor category. Field rates were used for all site personnel and the standard contractor rates were used for the instructors. The training time allocated is based on the relative complexity of the subsystem.

The recurring station operations were costed by estimating the number and labor category of the site personnel required, and the number of shifts the station will be in operation. The NASA supplied field rates were used. A yearly recurring expenditure of 1% of the total material dollars was added for non-replaceable spare parts. The level and category of personnel used to estimate these recurring costs are shown in Tables 6-1 and 6-2 for the "full-up" and "baseline" design options respectively.

Table 6-1. Recurring Manpower Estimates (Full Up)*

Labor Category	CDPF	PGDF	ARCHIVE	DATA	DIS	SYSTEM WIDE	TOTAL
MANAGERS	-	2	-	1	1	5	9
ENGINEERS	1	11	-	4	1	4	21
SUPERVISORS	3	20	2	-	4	3	32
MGMT SUBTOTAL	4	33	2	5	6	12	62
LEAD TECHS.	3	15	-	3	4	4	29
OPERATORS	18	123	-	12	16	4	173
TECH SUBTOTAL	21	138	-	15	20	8	202
GOPHERS	3	15	12	-	4	-	34
CLERICAL & SUPPORT	-	34	4	1	1	31	71
CLERK SUBTOTAL	3	49	16	1	5	31	105
TOTAL	28	220	18	21	31	51	369

*2 spacecraft - 438 scenes/day.

Table 6-2. Recurring Manpower Estimates
(Baseline Option) *

Labor Category	CDPF	PGDF	ARCHIVE	DATA	DIS	SYSTEM WIDE	TOTAL
MANAGERS	-	1	-	1	1	3	6
ENGINEERS	1	3	-	4	1	3	12
SUPERVISORS	2	3	-	-	4	1	10
MGT SUBTOTAL	3	7	-	5	6	7	28
LEAD TECHS.	2	6	-	3	4	-	15
OPERATORS	6	25	-	12	12	2	57
TECH SUPPORT	8	31	-	15	16	2	72
GOPHERS	1	4	6	-	-	-	11
CLERICAL & SUPPORT	-	6	-	1	1	5	13
CLERK SUBTOTAL	1	10	6	1	1	5	24
TOTAL	12	48	6	21	23	14	124

*1 spacecraft - 50-100 TM scenes/day

6.4 COST ESTIMATES

For this study, two cost estimates of the Data Processing Facility, DPF were developed; these are:

1. Data Processing Facility (Full Up Option - 2 spacecraft - 438 scenes/day)
2. Data Processing Facility (Baseline Option - 1 spacecraft - 50-100 TM scenes/day)

The cost estimates for each of these are summarized in Tables 6-3 and 6-4 for the "Full Up" and "Baseline" options. They are presented in their cost breakdown structure format in Figures 6-2 and 6-3, again respectively for the "Full Up" and "Baseline" design options.

Table 6-3. Cost Summary - Data Processing Facility (Full Up Option)

NON RECURRING COSTS

Cost Element	CDPF	PGDF	DATA	DIS	TOTAL
SYSTEM ENGINEERING	144	576	288	288	1296
EQUIPMENT DESIGN	1879	9029	1403	1997	14308
SOFTWARE	74	593	2178	631	3476
SYSTEM INTEGRATION	120	475	192	88	875
SITE INSTALLATION	143	213	160	103	619
TRAINING	108	352	160	108	728
PROGRAM MANAGEMENT	352	1120	336	312	2120
	2820	12358	4717	3527	23422
			SYSTEM WIDE		3816
		TOTAL NON-RECURRING			27238

RECURRING COST (PER YEAR)

	CDPF	PGDF	DATA	DIS	TOTAL
MANPOWER	683	5422	550	759	7414
MATERIAL	15	2088	12	17	2132
	698	7510	562	776	9546
			SYSTEM WIDE		1048
		TOTAL RECURRING			10594

TOTAL THROUGH FEE		
NON RECURRING	=	32,958
RECURRING/YEAR	=	12,819

1976 DOLLARS X 1000

THRU FEE = USE OF 10% FEE AND 10% CONTINGENCY

Table 6-4. Cost Summary - Data Processing Facility (Baseline Option)

NON RECURRING COSTS

Cost Element	CDPF	PGDF	ARCHIVE	DATA	DIS	TOTAL
SYSTEM ENGINEERING	96	307	25	288	288	1004
EQUIPMENT	1523	3999	577	1403	1515	9017
SOFTWARE	74	593	--	2178	631	3476
SYSTEM INTEGRATION	72	345	3	192	88	700
SYSTEM INSTALLATION	95	169	18	160	103	545
TRAINING	48	88	--	160	50	346
PROGRAM MANAGEMENT	256	615	50	336	312	1569
	2164	6116	673	4717	2987	16657
SYSTEM WIDE						3080
TOTAL NON RECURRING						18737

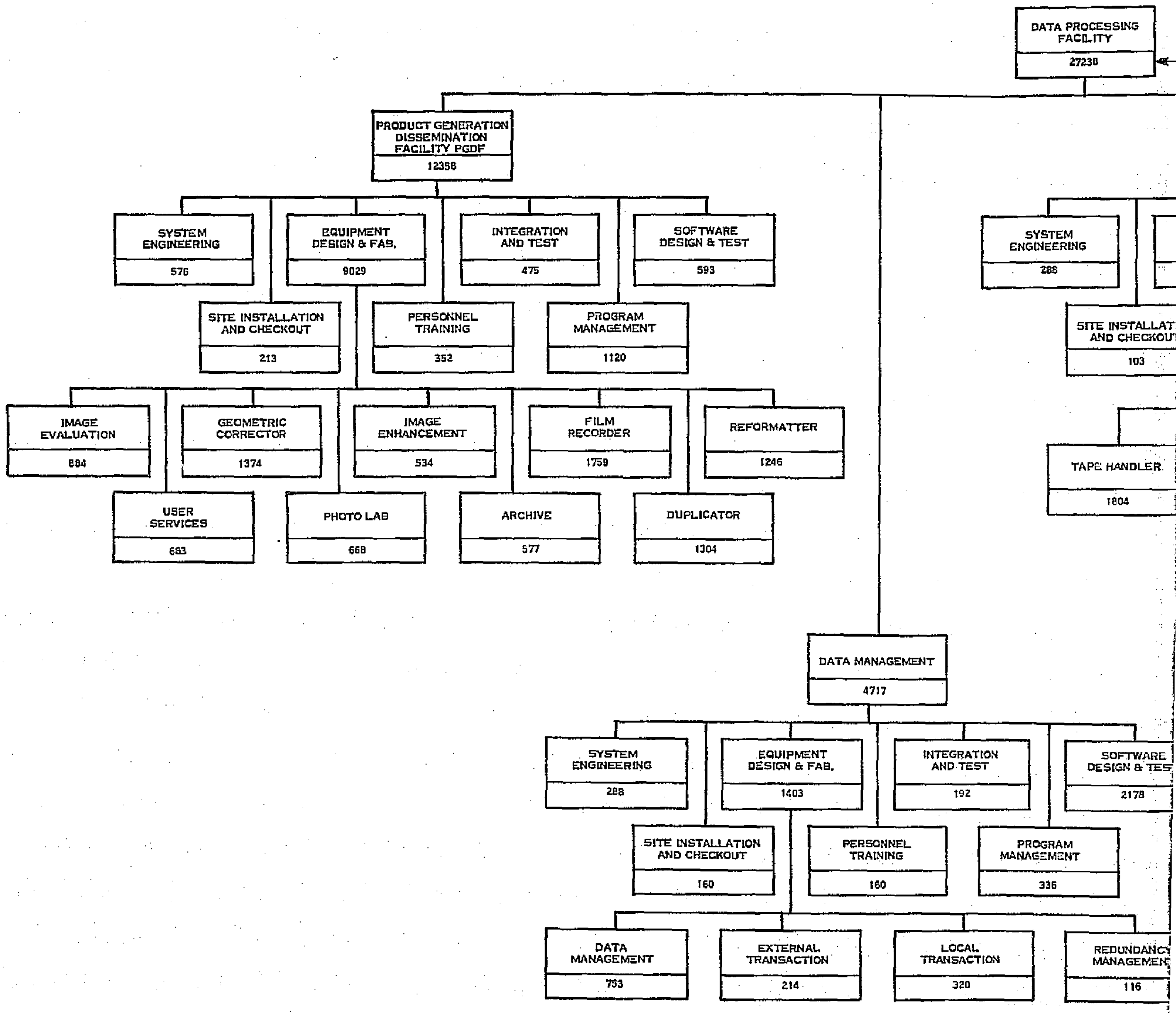
RECURRING COST (PER YEAR)

MANPOWER	312	1124	82	550	610	3586
MATERIAL	12	40	250	12	9	386
	324	1164	332	562	619	3972
SYSTEM WIDE						370
TOTAL RECURRING						4342

TOTAL THROUGH FEE	
NON RECURRING	23,882
RECURRING/YEAR	5,254

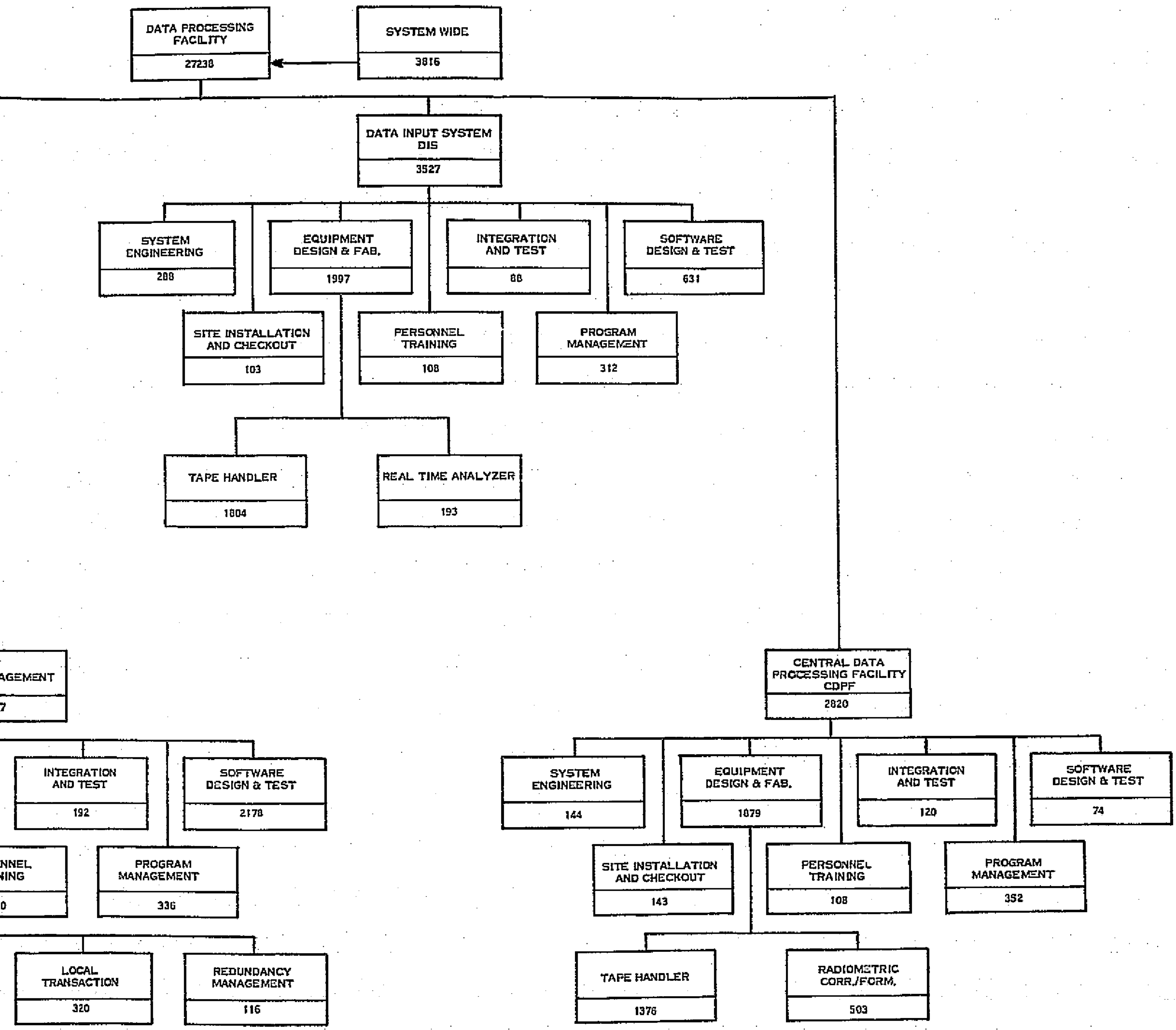
1976 DOLLARS X 1000

THRU FEE = USE OF 10% FEE AND 10% CONTINGENCY



1976 DOLLARS X1000
DOES NOT INCLUDE FEE OR CONTINGENCY

Figure 6-2. Cost Breakdown Structure - Data Processing Facil



e - Data Processing Facility (Full-Up Option)

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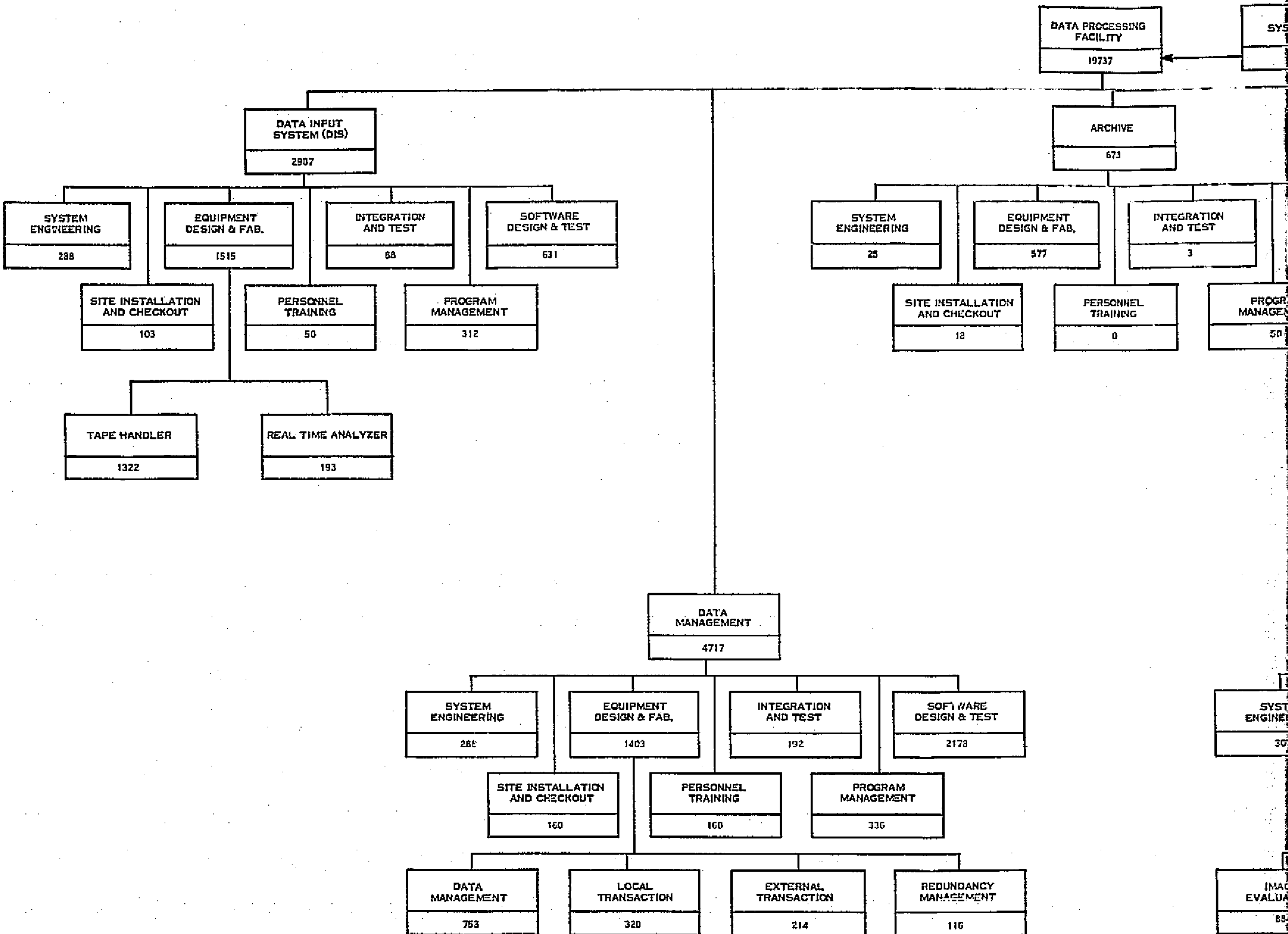
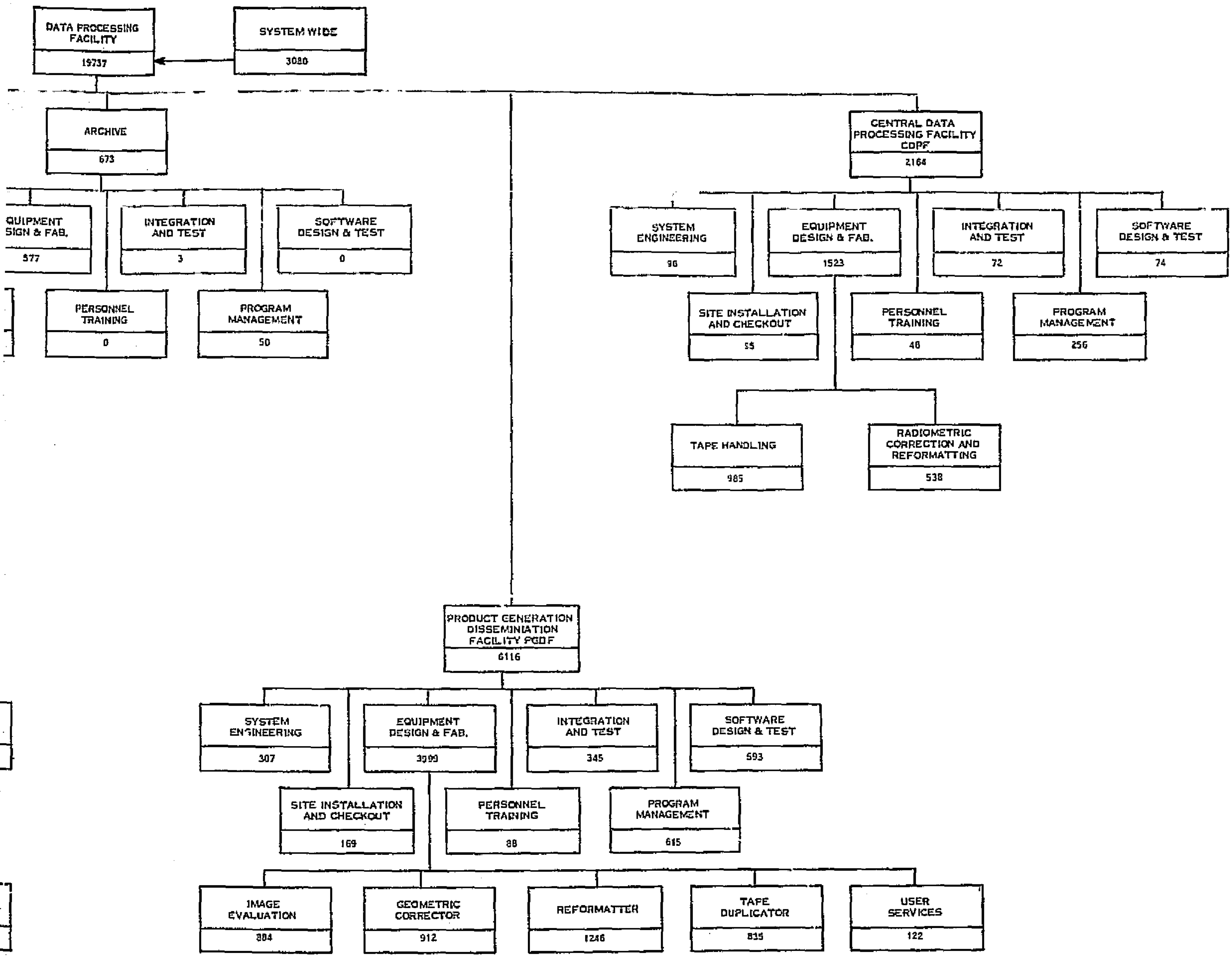


Figure 6-3. Cost Breakdown Structure - Data Process

FOLDOUT FRAME - /



Structure - Data Processing Facility (Baseline Option)

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